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LIMESTONE, DOLOMITE, AND SHELL RESOURCES OF THE COAST RANGES PROVINCE, CALIFORNIA

BULLETIN 197

CALIFORNIA DIVISION OF MINES AND GEOLOGY
Sacramento, California, 1978

LIMESTONE, DOLOMITE, AND SHELL RESOURCES OF THE COAST RANGES PROVINCE, CALIFORNIA

By
Earl W. Hart

1978

BULLETIN 197

CALIFORNIA DIVISION OF MINES AND GEOLOGY
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ABSTRACT

This report covers the Coast Ranges province—a 30,000-square-mile area of coastal California between the Oregon border and the city of Ventura, nearly 600 miles southeast. To facilitate discussion of the limestone, dolomite, and shell resources, this elongate province is divided into three regions—northern, central, and southern. The deposits are grouped into 14 districts within these regions.

The large population and high industrialization of the San Francisco Bay area, located in the central Coast Ranges region, has provided the main stimulus for exploration and development, particularly of the larger deposits. However, numerous small deposits of limestone, including some very impure ones, have been developed locally as sources of lime and crushed stone for construction uses. Altogether, roughly 100 deposits of limestone, dolomite, and shells have been developed commercially in the Coast Ranges province. A diversity of carbonate materials has been used, including metamorphic crystalline limestone and dolomite (Sur Series), fine, dense cherty limestone (Franciscan Formation), Quaternary spring deposits (travertine, calcareous tuff, onyx marble, and coliche), late Quaternary shells (San Francisco Bay mud), hard bioclastic limestone (Voqueros Formation), and dense, impure, bituminous dolomite (Monterey Formation), plus a variety of mostly impure sedimentary limestones ranging in age from Jurassic to Quaternary.

From 1850, when commercial production began, to 1968, an estimated 169 million tons of limestone, dolomite, and shells were produced in the Coast Ranges province. Of this, more than 86 percent come from the central Coast Ranges region around the San Francisco Bay district, and almost all of the rest come from the southern Coast Ranges region. Geologically, 37 percent of the production was limestone from the Franciscan Formation; 32 percent was crystalline limestone and dolomite from the Sur Series and similar metamorphic rock units; 19 percent was oyster shells from San Francisco Bay; 7 percent was from Quaternary spring-associated deposits; and about 4 percent was from other formations.

During the 1966–1968 period, there were 13 active operations at 11 different deposits and deposit groups in the Coast Ranges. Eight of these operations were in the central region, and five were in the southern region. The products were quarried and dredged and included: (1) limestone used for cement, aggregate, road base, riprap, building stone, decorative material, soil conditioning, livestock feed, beet sugar refining, and glass manufacture; (2) shells used for cement, livestock feed, and soil conditioning; and (3) dolomite used for refractory purposes, manufacture of magnesium compounds, roofing and landscape rock, aggregate, road base, riprap, soil conditioning, marking athletic fields, glass manufacture, whiting, and filter rock.

Reserves of raw carbonate materials other than those associated with deposits currently under development are fairly limited in distribution and kind. The northern Coast Ranges contain only minor reserves of limestone. The central Coast Ranges contain moderate to large reserves of cherty Franciscan limestone, crystalline limestone, and shells associated with bay mud; however, most of the better quality and larger deposits are already under development. Limestone reserves of the southern Coast Ranges region, particularly at the Pico Blanco deposit in Monterey County, are very large. High-quality crystalline dolomite in the southern region is present in modest but economically important amounts; less pure dolomite of the Monterey Formation is much more extensive, but development has been limited largely to aggregate and other construction uses. In spite of the obvious economic potential of certain deposits in the Coast Ranges, development of several is severely limited because of conflicting interests with urban, recreational, and wilderness developments and plans.

PREFACE

Because of the long delay in issuing this bulletin, the reader should be aware that most of the data presented are based on field work and literature review conducted from 1962 to 1965. The reader is referred to the paragraph under Purpose and Time of Investigation (p. 3) for a more complete explanation.

Despite the delay in publication, the material presented here is believed to be largely valid and useful.

EARL W. HART

April 16, 1978

LIMESTONE, DOLOMITE, AND SHELL RESOURCES OF THE COAST RANGES PROVINCE, CALIFORNIA

By Earl W. Hart

INTRODUCTION

This report includes a discussion of all of the known limestone, dolomite, and shell deposits of the north-west-trending Coast Ranges, except those of the Frazier Mountain area at the southeast end of the ranges. The carbonate deposits of the Santa Ynez Mountains, which are part of the Transverse Ranges, are included with the deposits of the Coast Ranges for convenience (figure 1).

The Coast Ranges carbonate province defined by this report (figure 1) covers 30,000 square miles, nearly one-fifth of California. It extends southeasterly for 600 miles from the Oregon border to southwest Ventura County and is at most 70 miles wide between the Pacific Ocean and the Great Valley. The area is not only extensive, but its complex geologic history has permitted a wide variety of carbonate deposits to develop. To facilitate discussion of the deposits, the Coast Ranges are subdivided somewhat arbitrarily into three subprovinces or regions—northern Coast Ranges (A), central Coast Ranges (B), and southern Coast Ranges (C). The deposits are discussed geographically from north to south by regions and by districts within each region (Contents and figure 1). Deposits within each district are discussed in alphabetical order.

The deposits are located on the district maps by number from north to south. The names of all deposits, including known synonyms, are listed alphabetically in the Index to Deposits at the end of this report.

Development and Production

Approximately 100 carbonate deposits have been productive in the Coast Ranges province. In addition, many more undeveloped deposits have been cited in the literature as possessing economic potential. Because of extensive changes in transportation, mining, processing, and other economic factors over the years, the majority of the deposits no longer are of economic interest as sources of industrial limestone and dolomite. However, some of these deposits may be of local value as sources of crushed stone or building stone or may be useful in some other way.

Total production of limestone, dolomite, and shells in the Coast Ranges through 1968 approximates 169 million tons. Referring to table 1, it can be seen that the central region has accounted for 86 percent of the total production. The principal limestone reserves and all of the dolomite reserves, however, are located in the southern region although substantial reserves of limestone and shells are available in the central region. In the 1966–1968 period, there were 13 active commercial producers of limestone, dolomite, and shells in the Coast Ranges province. The average yearly production of about 6 million tons was obtained from the following 11 deposits (with designated districts): Tolenas Springs (North Bay); San Francisco Bay Shell and Rockaway (San Francisco Bay); Permanente (Santa Clara); San Vicente and Pacific Limestone Products (Santa Cruz); Bryan and Pearce-Twohy, Natividad, and Westvaco (Gabilan Range); Lime Mountain (Southern Santa Lucia); and Missile City (Santa Ynez) (see plate 1).

Table 1. Estimated total production of limestone, dolomite, and shells for the Coast Ranges, by regions and formations through 1968.

<i>Formation and principal rock types</i>	<i>Estimated production (1,000,000 tons)</i>
NORTHERN COAST RANGES (A)	
Miscellaneous limestone	Minor
CENTRAL COAST RANGES (B)	
"Sur Series", crystalline limestone	34
Franciscan Formation, limestone and associated chert ..	62.5
Quaternary travertine, calcareous tufa, caliche	13
Quaternary shells of San Francisco Bay	33
Miscellaneous and undetermined	2.5
Subtotal	145.0
SOUTHERN COAST RANGES REGION (C)	
Sur Series, crystalline limestone	9
Sur Series, crystalline dolomite	10.5
Vaqueros Formation, limestone	1.5
Monterey Formation, dolomite and dolomitic limestone ..	2
Miscellaneous limestone and marl	1
Subtotal	24.0
Grand total	169.0

Figure 1. Index map of Coast Ranges limestone and dolomite province.

Deposit Descriptions

An attempt was made to describe all of the deposits in a systematic manner; and, where possible, data are provided on location, ownership, history, geology, development, production, estimated reserves, and pertinent references—generally in that order.

Almost all of the large deposits and many of the small ones in the Coast Ranges province were examined by this writer or Oliver E. Bowen (geologist, Division of Mines and Geology, from 1947 to 1968; now a consulting geologist). This investigator's property visits were conducted mainly between April 1962 and February 1964, whereas Bowen's visits extend over a much longer period (mainly before 1962). Limestone, dolomite, and shell deposits not examined include numerous minor ones plus some that have been adequately described in the literature and a few that could not be reached or located. Virtually all deposits cited previously in the literature, regardless of their economic significance, are considered in this report.

Samples and Chemical Analyses

Most chemical analyses presented herein are of hand or grab samples believed by the sampler to be representative of the compositional variations at a given carbonate deposit. The representativeness of a given sample or set of samples, however, depends on the acuity of the sampler, the accessibility and extent of deposit outcrops, and the degree of weathering. In some cases, processed or partly processed carbonate materials (shells and other materials) were sampled from stockpiles and waste piles, sometimes to check beneficiated and waste materials or simply because some deposits were inaccessible. For a variety of reasons, many deposits were not sampled at all.

Analyses of samples by commercial laboratories were made prior to 1960. Most, if not all, of these analyses were by wet chemical methods. Most analyses since 1960 were made by Division of Mines and Geology laboratory staff. Until mid-1963, these were done mainly under the supervision of Charles W. Chesterman, using rapid analytical techniques. In 1963, analytical techniques were changed to a combined wet chemical and x-ray fluorescent method under the supervision of Matti Tavela. Analyses made by various companies and individuals are believed to have been done by wet chemical methods.

Because of the above variables—particularly the inherent sampling problems—the chemical analyses presented herein should be viewed only as a general guide to the composition of the deposits sampled.

Reserves

All reserve figures for deposits described herein are estimates based on limited data—generally not including drill data. These estimates are of carbonate materials believed to be recoverable under present (1972) economic and mining conditions. The type of carbonate material (limestone, limestone and chert, dolomite, shells) comprising each deposit is indicated where reserve figures are estimated. Where little or no subsurface data are available or where deposits are poorly exposed, estimated reserves are presented in tons per foot of depth, and no attempt is made to estimate economically recoverable material.

Definitions

Carbonate rock, as used herein, is a general term that includes all limestone, dolomite, shell, travertine, calcareous tufa, onyx, caliche, marl and unspecified mixtures of these. Definitions of the more specific terms used in this report are:

- *limestone*: A sedimentary rock composed mostly of detrital or chemically deposited calcite (calcium carbonate). Metamorphosed limestone (marble) is recrystallized calcite and is referred to as *crystalline limestone*. *Biohermal limestone* is a limestone composed largely of firmly cemented fragmental fossil debris.
- *dolomite*: A sedimentary rock, often diagenetically altered, composed mainly of the mineral dolomite (double carbonate of calcium and magnesium). A metamorphosed dolomite (marble or dolomite marble) is referred to as *crystalline dolomite*.
- *shell deposits*: Uncemented to weakly cemented accumulations of shells and shell debris; pure to very impure calcium carbonate.
- *travertine*: Fine to sometimes coarse crystalline, dense to vuggy, banded rock composed of calcium carbonate; formed from surface water at or near the earth's surface, generally near springs.
- *calcareous tufa*: A very porous, commonly fibrous variety of travertine.
- *onyx or onyx marble*: A fine-grained, delicately banded variety of travertine.
- *caliche*: An impure carbonate deposit formed at or near the surface in porous soils. May be associated with calcareous tufa or other spring deposits.

- *marl*: An impure fine-grained limestone or dolomite containing substantial amounts of noncarbonate minerals or grains.

The above types of carbonate materials are not always distinct and some materials may be intermediate between two or three of the above classes. Also, many deposits contain two or more distinct kinds of carbonate materials.

Purpose and Time of Investigation

This investigation was initiated by the California Division of Mines and Geology in 1962 as part of a statewide survey of the limestone, dolomite, and shell resources of California under the supervision of Oliver E. Bowen in association with several other Division geologists. At that time, the study was divided areally into six carbonate provinces—Klamath Mountains, Coast Ranges, Sierra Nevada, Basin Ranges, Mojave Desert, and Transverse Ranges and Peninsular Ranges—and, together with an introductory part (Bowen, Evans, and Gray, 1973), the seven-part report was intended to be published as one Bulletin. The initial report on the Coast Ranges province was submitted for publication processing by this writer in

March 1965. Because of problems encountered in timing and coordinating the bulky, multi-authored report and the delays in completing parts of the investigation, it was decided to publish the various parts separately as they became ready. This report was considerably delayed in the meantime and was reorganized in October 1969. At that time, statistics were updated through 1968 and a little descriptive data added. Significant information obtained since October 1969 has been included as footnotes.

Acknowledgments

Unpublished field data and sample analyses supplied by Oliver E. Bowen and other geologists of the California Division of Mines and Geology, as well as employees of the U.S. Geological Survey and several other agencies and private companies, are gratefully acknowledged. The many courtesies provided by numerous operators and property owners are also appreciated. All available published and unpublished data were used to evaluate the carbonate deposits and are cited wherever practical. The author is indebted to Oliver E. Bowen and Richard M. Stewart for critically reviewing the manuscript prior to publication.

NORTHERN COAST RANGES REGION (A)

This region is the northernmost of three arbitrary subdivisions of the Coast Ranges limestone, dolomite, and shell province. It encompasses all of the Coast Ranges in Colusa, Del Norte, Glenn, Humboldt, Lake, Mendocino, Tehama, Trinity, and Yolo Counties. The region is flanked on the west by the Pacific Ocean, on the east by the Sacramento Valley, and on the northeast by the Klamath Mountains (figure 1 and plate 1). A narrow strip of the northern Coast Ranges extends northward into Oregon. The region is rather sparsely populated, the largest city being Eureka with 28,137 people in 1960. The economy is based largely on lumbering, recreation, agriculture, and fishing. In general, the region is mountainous and many parts are not easily accessible. Major transportation facilities are limited by the north- and northwest-trending ranges although most of the region is served by highway, rail, or port facilities.

There are few limestone and no dolomite deposits of economic interest even though occurrences of carbonate rock are common. Limestone has formed under a variety of conditions since Late Jurassic time. Perhaps the oldest limestone occurs as thin beds and lenses in shale of the Knoxville Formation (Upper Jurassic) exposed in the low hills of the Coast Ranges that flank the Sacramento Valley. Minor beds, lenses, and concretions also are found in Cretaceous shales that conformably overlie the Knoxville. Much of the rest of the northern Coast Ranges is underlain by sedimentary and volcanic rocks generally assigned to the Franciscan Formation of Late Jurassic and Cretaceous age. These rocks consist of graywacke, chert, shale, volcanic rocks, and minor amounts of limestone. Most of the limestone is thin bedded, usually interstratified with chert and commonly associated with altered volcanic rocks (greenstone). In a few cases, massive limestone is associated mainly with graywacke of the Franciscan Formation.

Limestone that is more or less impure is found in the marine Pullen Formation (Miocene and/or Pliocene) near Eureka and as lake beds or marls in the Tehama and Cache Formations (Pliocene and/or Pleistocene) that lie east of Clear Lake and along the

western side of the Sacramento Valley. In addition, numerous surficial deposits of travertine, onyx marble, and calcareous tufa were formed in the vicinity of mineral springs during Quaternary time. Beds of oyster shells may exist in the mud in modern or young fossil bays along the coast although no such deposits have been reported.

About 10 deposits have been utilized for limestone in the northern Coast Ranges. Total production is not known but probably does not exceed a few tens of thousands of tons of limestone. Practically all of this was used as agricultural limestone, to make lime for construction use, and for mercury retorting. The only deposit of sufficient size and purity to be of significant economic interest is the Fashauer Ranch deposit in Mendocino County. Some of the other deposits may be of local use, particularly in road construction or for agricultural purposes. Some of the travertine and other surficial deposits, as well as the red limestone of the Franciscan Formation, may be of interest as sources of ornamental and architectural materials. The red Franciscan limestone has been referred to as the Laytonville-type limestone and is described in detail by Bailey *et al.* (1964, p. 68-77) and Garrison and Bailey (1967, p. B94-B100).

The limestone deposits of the northern Coast Ranges are shown on plate 1A and are discussed below in alphabetical order within each district. The districts of the region are listed in geographic order from north to south.

HUMBOLDT DISTRICT (A-1)

Minor amounts of limestone from the Richter, Moore, and McClellan Ranch deposits have supplied local agricultural needs at times in the past. Some lime also was made at the Jacoby Creek deposit many years ago. However, none of the known deposits is large enough to be considered of significant future value.

Hackett deposit. Location: N $\frac{1}{2}$ sec. 16, T. 1 N., R. 1 W., H., 4 $\frac{1}{2}$ miles west-southwest of Rio Dell; Scotia 15-minute quadrangle. Ownership: Mel Hackett, Vernon Hackett, *et al.*, Rio Dell (1963).

White, gray, and red limestone is described by B. A. Ogle (1953, p. 82-83) as a "continuous bed" traceable for half a mile northwest of the west fork of Howe Creek, where it crops out strongly. The bed is reported to be 75 feet thick, to strike N 60° W, and to dip 45° N. Others (Averill, 1941, p. 516; Logan, 1947, p. 237) had previously reported similar limestone to crop out as a single 20-by-30-foot exposure in the same vicinity. This writer was unable to locate any limestone outcrops on the west fork of Howe Creek in August 1963. Neither were the owners aware of any significant limestone outcrops in the vicinity, where they have worked and hunted for many years. No positive explanation can be offered for this anomalous "disappearance". However, it is possible that floods and landslides, created by the major storms of 1955-56, destroyed or covered the exposures in the creek. This suggestion would be more plausible if the Hackett deposit, where traversed by Howe Creek, were comprised of small, detached masses of limestone rather than continuous masses.

In 1963, the west fork of Howe Creek contained scattered boulders of light dove-gray and dark reddish-brown limestone. This float could be traced nearly a quarter of a mile upstream from its main confluence to a small northwest tributary gulch. At this point, there was an increase of limestone float, and some limestone fragments were observed in a landslide exposed in the gulch. Above the gulch, only a few boulders of a dark gray limestone were noted. Most of the limestone float is very similar to limestone of the Franciscan Formation, being fine grained, dense, sometimes containing Foraminifera, and generally brecciated or sheared. The visible impurities appear to be silica and iron oxide minerals, but most of the light-colored limestone appears to be of a high-calcium type.

There is no record of development of this limestone. Moreover, the existence of a significant limestone deposit has not been established.

Jacoby Creek deposit. Location: NW¼NW¼ sec. 13, T. 5 N., R. 1 E., H., 2½ miles southeast of Bayside and 7 miles east of Eureka; Eureka 15-minute quadrangle. Ownership: F. B. Barnum, Inc., and R.W. Bull, Eureka (1941).

Limestone from this deposit was burned for lime many years ago, as shown by the remnant of an old brick kiln nearby (Averill, 1941, p. 516). The deposit was tested as a source of raw material for cement prior to 1916 but was never developed commercially for that purpose.

The deposit reportedly consists of a single exposure 50-by-20-by-15 feet. Samples collected by Oliver E. Bowen show the limestone to be dense, fine grained to partly crystalline, grayish tan to light olive, and mottled white with irregularly veined calcite. One sample contained numerous fossil fragments which suggest a Late Cretaceous age. Although the limestone appears to be high in calcium and relatively free from impuri-

ties, the deposit is too small to be of more than local interest.

Other references: Lowell, 1916, p. 393; Logan, 1947, p. 238; Irwin, 1960, p. 37.

Johnston deposit. Location: Secs. 4 and 9, T. 2 S., R. 1 W., H., 5 miles east of Petrolia and 12 miles south-southeast of Scotia; Scotia 15-minute quadrangle. Ownership: Johnston Estate and T. A. Johnston, Petrolia (1941).

Small outcrops of limestone, presumably of the Franciscan Formation, are exposed intermittently for 2 miles in a northwest direction. The deposits are situated in a remote area within or close to the Mattole fault zone. The limestone has not been worked and probably is not present in economic amounts.

References: Averill, 1941, p. 517; Logan, 1947, p. 238.

McBride Ranch deposit. Location: Secs. 26 and 27, T. 1 N., R. 2 W., H., on Southmayd Ridge; Cape Mendocino 15-minute quadrangle. Ownership: McBride Ranch.

According to Robert D. Nason of the U.S. Geological Survey (personal communication, 1967), a bed or series of beds of coarse-crystalline white limestone up to 20 feet thick crops out for over a mile. The beds strike northwest and stand vertically. The associated rocks are chiefly graywacke and chert. The deposit is undeveloped.

McClellan Ranch deposit. Location: Sec. 5, T. 1 N., R. 1 W., H., 5 to 6 miles west of Rio Dell and 7 miles south-southwest of Fortuna; Scotia 15-minute quadrangle. Ownership: E.S. McClellan (1941).

The deposit has been described as soft, white, porous, calcareous tufa covering an acre of land to a depth of 3 feet (Averill, 1941, p. 517). It is reported to contain 99% calcium carbonate and has been used on the McClellan Ranch (Ogle, 1953, p. 83).

Other reference: Logan, 1947, p. 238.

Moore deposit. Location: Sec. 19(?), T. 5 N., R. 2 E., H., 5 miles southeast of Bayside and 8 miles east of Eureka; probably Blue Lake 15-minute quadrangle. Ownership: J. A. Moore, Blue Lake (1916).

A small deposit of limestone situated near the Jacoby Creek deposit is reported to have been quarried for local farm use in 1913. An analysis of the limestone shows 53.61% CaO, 1.41% SiO₂, 0.35% Fe₂O₃, 0.56% Al₂O₃, and a trace of MgO.

References: Lowell, 1916, p. 394; Averill, 1941, p. 516; Logan, 1947, p. 238.

Parkhurst Ridge deposit. Location: Sec. 23, T. 2 S., R. 1 W., H., 2 miles northeast of Upper Mattole School; Scotia 15-minute quadrangle. Ownership: Ben Etter, Honeydew (1967).

According to Robert D. Nason of the U. S. Geological Survey (personal communication, 1967), the deposit crops out over several acres on Parkhurst Ridge. The limestone is fine grained, red, and ferrugi-

nous. The beds are poorly defined but appear to strike generally northwest and to dip nearly vertically. The enclosing wall rocks are pillow basalt. The attractive appearance of the rock may make it marketable for an ornamental garden or construction stone. The deposit is undeveloped.

Richter (Riektter) deposit. Location: NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 11, T. 1 N., R. 1 W., H., 2 miles southwest of Rio Dell; Scotia 15-minute quadrangle. Ownership: W. G. Fritz and A. and O. Richter, Rio Dell (1963).

The Richter deposit is situated just west of the crest of a northwest-trending ridge and is readily accessible by road from Rio Dell. Low limestone outcrops and float cover an area roughly 600 feet long in a northeast direction by 150 to 200 feet wide. The pattern of outcrops suggests that the deposit is gently dipping. It is associated with siltstone and calcareous sandstone of the Pullen Formation of late Miocene to early Pliocene age (Ogle, 1953, p. 82). The limestone is characteristically buff colored, hard, fossiliferous, bituminous, sandy, and silty. Chemical analyses made by Matti Tavela and Lydia Lofgren from samples obtained by this writer in 1963 show the limestone to be somewhat impure:

Sample	CaO	MgO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	K ₂ O	P ₂ O ₅	Ign. loss
R-1	48.1%	0.73%	9.2%	0.50%	1.0%	0.20%	0.06%	39.7%
R-2	45.2	0.81	7.4	1.2	0.78	0.25	0.06	41.6

Development of the deposit is limited to a single quarry 75-by-25 feet with a maximum face of 10 feet. Minor amounts of limestone were produced for agricultural purposes beginning about 1915. There has been no recent production. The limestone deposit appears to be a thin cap, and reserves are probably small.

Other references: Averill, 1941, p. 517; Lagon, 1947, p. 238.

White Woman deposit. Location: NE $\frac{1}{4}$ sec. 29, T. 4 S., R. 5 E., H., 9 miles east of Garberville and 1 $\frac{1}{2}$ miles east-northeast of Harris; Alderpoint 15-minute quadrangle. Ownership: A.A. Smith, Harris (1963).

Small exposures of Franciscan limestone are reported at intervals for a quarter of a mile. The largest of these forms a cliff 35 feet long and 10 feet high (Averill, 1941, p. 518). The deposit consists of Calera-type limestone and thin chert interbeds. The limestone is typically dense, fine crystalline, light dove gray to pale grayish brown, and apparently high in calcium. A sample submitted by the owner was analyzed by the Division of Mines and Geology laboratory staff in 1963 and showed the following chemistry:

Sample	CaO	MgO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	K ₂ O	P ₂ O ₅	Ign. loss
WW-1	53.8%	0.30%	2.5%	0.44%	0.23%	0.06%	0.07%	43.0%

The deposit has never been worked. There appears to be little economic potential, as reserves are undoubtedly small and the deposit is poorly situated

with regard to transportation, accessibility, and markets.

Other reference: Lagon, 1947, p. 239.

MENDOCINO DISTRICT (A-2)

The largest known limestone deposit in the northern Coast Ranges is the Fashauer Ranch deposit of western Mendocino County. The deposit is undeveloped, as are the Fisher Ranch and Usal deposits. Only the Quinan Ranch deposit has been worked, with total production to 1968 amounting to about 700 tons of agricultural limestone.

Fashauer Ranch deposit. Location: NW $\frac{1}{4}$ sec. 2, T. 14 N., R. 16 W., M.D., 6 miles east-southeast of Elk; Navarro 15-minute quadrangle. Ownership: Anthony and Francis Fashauer, Greenwood Road, Elk (1962).

The Fashauer Ranch limestone is exposed in a poorly accessible area just south of an east tributary of Greenwood Creek at an elevation of 700 feet. It constitutes a northwest-trending deposit, possibly 600 feet long by 200 to 300 feet wide. Although poorly stratified, the deposit appears to dip steeply southwest into the hill. The limestone is pale grayish brown, faintly mottled, finely crystalline, bituminous, fractured, and cut by veinlets of calcite and quartz. No chert beds were noted in the deposit, although the limestone and surrounding graywacke may be part of the Franciscan Formation. Smaller limestone bodies similar to the Fashauer Ranch deposit are said to exist on nearby ranches. Chemical analyses made of five samples taken over a length of 200 feet across the strike of the deposit by U.S. Steel Company indicate the limestone to be of uniform quality (personal communication with the owners, 1962). All of the samples showed at least 54% CaO and averaged 1.55% SiO₂, 0.65% MgO, 0.20% Fe₂O₃, and 0.45% Al₂O₃. Three random samples collected along the northeast side of the deposit and analyzed by Lydia Lofgren in 1962 show similar chemistry:

Sample	CaO	MgO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	P ₂ O ₅	Ign. loss
Fas-1	54.50%	0.43%	1.42%	0.10%	0.13%	0.03%	43.18%
Fas-2	53.25	0.85	2.86	0.12	0.11	0.03	42.30
Fas-3	54.00	0.51	1.81	0.21	0.19	0.03	42.88

There has been no development of the deposit, principally because of its inaccessibility and distance from markets. It appears to contain one of the largest reserves of good quality limestone in the northern Coast Ranges, probably in the order of 1 to 2 million tons. However, more prospecting is needed to determine the size, distribution, and presence or lack of such deleterious materials as chert interbeds in the limestone.

Fisher Ranch deposit. Location: NW $\frac{1}{4}$ sec. 36, T. 22 N., R. 15 W., M.D., 2 miles north of Laytonville; Laytonville 15-minute quadrangle. Ownership: Marshall and Pauline C. Fisher, Laytonville (1953).

Limestone of the Franciscan Formation is exposed as a series of outcrops along a low hill a few hundred feet east of U.S. Highway 101. As indicated by exposures and limestone float, the deposit extends over a length of about 600 feet and a maximum width of 100 feet. The deposit consists of a sequence of well-bedded, massive limestone interleaved with thin chert beds and lenses. Consistent bedding exposures show the deposit to strike N 10° E and dip 70 to 80° E. Limestone along the west side of the deposit is typically rust red to reddish brown, dense, fine grained, foraminiferal, and cut by numerous veinlets of calcite. This part of the sequence grades easterly into yellowish-gray, red-mottled limestone of otherwise similar character. Both types of limestone appear to be high in calcium, the only visible impurities being iron oxide in the red varieties and discrete chert beds. Similar but smaller limestone deposits are exposed in road cuts to the south, three-quarters of a mile north of Laytonville.

A chemical analysis of the Fisher Ranch limestone is reported to be 93.16% CaCO₃, 0.39% MgCO₃, 0.69% Fe₂O₃ and Al₂O₃, and 5.56% insoluble (Logan, 1947, p. 254). Two additional analyses of the yellowish (FR-1) and reddish (FR-2) limestone were made by Matti Tavela and Lydia Lofgren from samples collected by this writer in 1963:

Sample	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	K ₂ O	P ₂ O ₅	Ign. loss
FR-1.	2.5%	0.07%	0.30%	0.38%	53.2%	0.00%	0.08%	43.2%
FR-2.	1.0	0.00	0.43	0.84	53.8	0.00	0.07	43.6

There has been no development of the deposit, and the limestone would have to be beneficiated for most limestone uses. However, the limestone shows rather striking colors and may be useful as a source of colored granules or as a decorative material. The deposit is readily accessible, but it is about 13 miles from the nearest rail facility at Longvale. Reserves of limestone are estimated to be 300,000 tons per 100 feet of depth. Because of a maximum relief of approximately 50 feet, reserves above local base level are relatively small.

Other references: O'Brien, 1953, p. 361; Irwin, 1960, p. 35, 43; Bailey and others, 1964, p. 75.

Quinan Ranch deposit. Location: Sec. 26, T. 17 N., R. 13 W., M.D., 2 miles northwest of Laughlin and 10 miles north-northwest of Ukiah; Willits 15-minute quadrangle. Ownership: Grace T. Post (1953).

This surficial deposit has been described by Logan (1947, p. 254) as terraces of travertine and calcareous tufa formed from spring action near the top of a ridge. The springs issue along a fault that strikes west and dips 61° S. One terrace, at an elevation of 2,000 feet, is 250 feet long by 100 feet wide. To the east and 35 feet below the first terrace, a lower terrace covers an acre or less in area. This is developed by a pit 27-by-50 feet with a depth of 10-to-15 feet. A 6- to 8-foot thick bed of travertine, underlain by soil and angular rock fragments, is exposed here. A chemical analysis made of

the travertine shows 94.97% CaCO₃, 1.51% MgCO₃, 0.24% Fe₂O₃ and Al₂O₃, and 3.20% insoluble (Logan, 1947, p. 254).

Northwest Pacific Lime and Sulphur Company worked the deposit from 1930 to 1933. Based on the size of the pit and the thickness of the deposit, production must have been in the order of 700 tons. The carbonate material was trucked a few miles to a mill at Laughlin on the Northwestern Pacific Railroad. Here, the material was crushed and pulverized for use as a soil conditioner.

Other references: Averill, 1929, p. 462; O'Brien, 1953, p. 361.

Usal deposits. Location: Secs. 1 and 2, T. 23 N., R. 18 W., and secs. 26, 35, and 36, T. 24 N., R. 18 W., M.D., 16 miles south of Garberville; Piercy 15-minute quadrangle. Ownership: Not determined.

About 30 small lenses of limestone comprising two northwest-trending belts are mentioned in a report on manganese by Trask *et al.* (1950, p. 146-147). The limestone is light gray and fine grained, except near the manganese ore, where the color is pinkish. Most of the limestone lenses are less than 5 feet thick and 20 feet long, although one is 50 feet thick by 150 feet long. The limestone is reported to be similar to the limestone near Laytonville (Irwin, 1960, p. 43).

The limestone has never been used, and future development is limited by the size of the lenses and the remoteness of the area. However, other limestone deposits may exist nearby.

CLEAR LAKE DISTRICT (A-3)

Deposits of the Clear Lake district lie in Glenn, Colusa, Lake, and Yolo Counties (plate 1A). Small amounts of limestone were produced many years ago at the Manzanita and Wide Awake deposits, apparently for use in retorting mercury ore from the mines near Wilbur Springs. A little limestone was also quarried in Burns Valley as a source of lime in the late nineteenth century. None of the deposits appears to be of significant commercial value although some interest has been shown recently in the surficial deposits near Wilbur Springs as sources of decorative stone.

In addition to the deposits described below, limestone has been reported from sec. 19, T. 11 N., R. 7 W., M.D., where the Knoxville Formation is exposed. That same formation also is found in sec. 36, T. 13 N., R. 6 W., where the remains of an old lime kiln are reported (Logan, 1947, p. 248).

Surficial deposits of notable size have been described by Waring (1915, p. 183-184, 193-194, 196-198) at Highland, Dinsmore, Hough, and Grizzly Springs. A small, undeveloped deposit of onyx marble lies near Hullville in sec. 12, T. 18 N., R. 10 W., M.D., (Bradley, 1916, p. 225).

Burns Valley deposit. Location: T. 13 N., R. 7 W., M.D., near Clear Lake Highlands; Lower Lake 15-minute quadrangle. Ownership: Not determined.

Limestone from Burns Valley, north of the town of Lower Lake, apparently supplied two lime kilns owned by the Sulphur Bank Mining Company in the late 1800s (Crawford, 1894, p. 392). The source of lime rock has not been determined but may be the marl or limestone present in the Cache Formation. Limestone near Clear Lake Highlands is described as micro-crystalline and dolomitic and occurs in several beds 1 to 10 feet thick (Anderson, 1936, p. 634).

Other references: Bradley, 1916, p. 206; Logan, 1947, p. 248.

Capay Valley deposits. Location: T. 10 N., R. 2 and 3 W., and T. 11 N., R. 3 W., M.D., 17 to 20 miles west of Woodland; Guinda and Lake Berryessa 15-minute quadrangles. Ownership: multiple; not determined.

Limestone and marl deposits in Capay Valley between Capay and Guinda have been mentioned in the literature, but they have not been developed. Most of the hard limestone occurs as float on slopes and in streams and probably is derived from the large calcareous concretions and lenses common to the Upper Cretaceous shales. Analyses of float indicate the limestone to be relatively high in calcium but somewhat siliceous. The softer marl, reported from the foothills along Cache Creek, is believed to be from fresh water deposits locally present in the Plio-Pleistocene Tehama Formation.

The calcareous rocks of the lower Cache Creek area are of variable chemistry, and the deposits generally are too small to be of economic value. It is possible that the soft marl may be of local interest for agricultural purposes.

References: Bradley, 1916, p. 368; Logan, 1947, p. 350.

Chalk Mountain deposit. Location: S $\frac{1}{2}$ sec. 12, T. 14 N., R. 7 W., M.D., 6 miles northeast of Clearlake Oaks; Clearlake Oaks 15-minute quadrangle. Ownership: Not determined.

A spring deposit of calcium carbonate on the northwestern side of Chalk Mountain extends for 100 yards along the mountainside and for 75 feet downslope to the North Fork of Cache Creek (Waring, 1915, p. 196-197). There is no known development of this deposit.

Daniels deposit. Location: Sec. 21, T. 18 N., R. 6 W., M.D., 1 to 2 miles north of Stonyford and 20 miles southwest of Willows; Stonyford 15-minute quadrangle. Ownership: Not determined.

A "ledge of white marble" that "may be traced for a mile north and south along the east side of Stony Creek" is reported by Aubury (1906, p. 99).

The geology of the Stonyford quadrangle was mapped in detail by R. D. Brown, Jr., and Ernest Rich. Brown states (1964, personal communication) he has no record of limestone in sec. 21 and questions the location or descriptive data given by early writers. It is not likely such a distinct deposit would be overlooked in the course of detailed geologic mapping.

However, it is possible that thin lenses of limestone of the Knoxville Formation are present locally in sec. 21.

Other references: Bradley, 1916, p. 198; Logan, 1947, p. 237.

Lambert Ranch deposit. Location: Sec. 20, T. 16 N., R. 5 W., M.D., 2 $\frac{1}{2}$ miles northwest of Leesville and 14 miles west of Cortena on the Southern Pacific Railroad; Wilbur Springs 15-minute quadrangle. Ownership: Not determined.

Limestone from this deposit was burned for lime about 1889 (Aubury, 1906, p. 66). From the location given, the limestone probably is from the lower part of a thick sequence of Lower Cretaceous sedimentary rocks.

Other references: Bradley, 1916, p. 179; Logan, 1947, p. 220.

Manzanita deposit. Location: NE $\frac{1}{4}$ sec. 29, T. 14 N., R. 5 W., M.D., half a mile west of Wilbur Springs and 17 miles southwest of Williams; Wilbur Springs 15-minute quadrangle. Ownership: Not determined.

A southeast-trending bed of crystalline limestone is reported from the western part of the Manzanita mercury mine property. This property is underlain by the Knoxville Formation, which sometimes contains thin beds of limestone and marl interbedded with shale. The limestone was produced in a small way for local use in the early 1900s.

References: Forstner, 1903, p. 41; Aubury, 1906, p. 66; Bradley, 1916, p. 179; Logan, 1947, p. 220.

Nye deposit. Location: Secs. 1 and 12, T. 18 N., R. 8 W., M.D., 28 miles west of Willows; Stonyford 15-minute quadrangle. Ownership: Not determined.

A deposit of onyx marble is reported in the southwest part of Glenn County on the west side of Saint John Mountain. The property, which was part of the J.M. Nye Ranch, is not known to be developed.

References: Bradley, 1916, p. 198; Logan, 1947, p. 237.

Wide Awake deposit. Location: SE $\frac{1}{4}$ sec. 29 or SW $\frac{1}{4}$ sec. 28, T. 14 N., R. 5 W., M.D., 1 mile southwest of Wilbur Springs and 17 miles southwest of Williams; Wilbur Springs 15-minute quadrangle. Ownership: Not determined.

A deposit of limestone composed entirely of shells is reported on the Wide Awake quicksilver property. This was used locally prior to 1916. Other shell deposits in thin beds are mentioned as occurring in the same vicinity, one near the top of the hill in NE $\frac{1}{4}$ sec. 28. None of these deposits has been worked in recent years, and they probably are not of commercial interest.

References: Goodyear, 1890, p. 160, 161; Forstner, 1903, p. 42; Bradley, 1916, p. 179; Logan, 1947, p. 220.

Wilbur Springs deposits. Location: W $\frac{1}{2}$ T. 14 N., R. 5 W., and adjacent part of T. 14 N., R. 6 W., M.D.; Wilbur Springs 15-minute quadrangle. Ownership: Not determined.

Onyx marble, aragonite, calcareous tufa, and other types of carbonate material have been reported from

several localities northwest and west of Wilbur Springs. The following occurrences have been reported:

1. Brown orogonite from a thin vein of the "head of Sulphur Creek" was once shipped to England for sale. The vein was situated on 48 acres of land owned by California Onyx Company (Irelon, 1888, p. 159).
2. Brown, delicately banded orogonite, referred to as "Brown's agate", come from a locality about a mile west of Wilbur Springs where the material occurred as float (Goodyear, 1890, p. 156).
3. Hard, white calcium and magnesium carbonate rock, with enclosed shale fragments, is exposed as a prominent ledge below the Judge Moor tunnel near the Elgin mercury mine (Woring, 1915, p. 105-106).
4. A ledge of brown onyx marble crosses the creek half a mile upstream (W $\frac{1}{2}$ sec. 13, T. 14 N., R. 6 W.) from the Elgin mine. "The deposit has not been worked commercially" (Woring, 1915, p. 106).
5. A "capping" of brown, banded onyx marble a foot thick, 20 feet wide, and 150 feet long is reported to lie a mile north of the Elgin mine. This deposit was located in 1929 and was known as the Warwick group of claims (Logan, 1929, p. 292).

None of the deposits appear to have significant potential as sources of limestone, but some may be of interest as sources of ornamental material. It is reported that one of the deposits near the Elgin mine was worked in a small way in the early 1960s as a source of decorative stone.

Other reference: Logan, 1947, p. 220.

Unnamed deposit (near Abbott mine). Location: Near NE $\frac{1}{4}$ sec. 31, T. 14 N., R. 5 W., M.D., 18 to 19 miles southwest of Williams; Wilbur Springs 15-minute quadrangle. Ownership: Not determined.

Limestone has been reported near the Abbot mercury mine but has never been described. Perhaps it is related to the white deposit of calcareous tufa exposed in a road cut near the mine (C.W. Jennings, 1964, oral communication).

References: Crawford, 1894, p. 392; Brodley, 1916, p. 206; Logan, 1947, p. 248.

CENTRAL COAST RANGES REGION (B)

This region covers the central part of the Coast Ranges and an adjacent portion of the Sacramento Valley (plate 1B). It includes all of Alameda, Marin, Napa, San Francisco, Santa Clara, Santa Cruz, and Sonoma Counties, and parts of Contra Costa, Merced, Sacramento, San Joaquin, Solano, and Stanislaus Counties. Although San Francisco Bay and its related waterways physically subdivide the region, they also serve as important harbors around which a large population and attendant industries have become concentrated.

Topographically, San Francisco Bay is a drowned, northwestern extension of the Santa Clara Valley. The valley and bay are bordered on the west by the Santa Cruz Mountains and on the east by the extensive Diablo Range. The mountain and valley features north of San Francisco Bay are less distinctive, having many local names, but essentially constitute the southern end of the northern Coast Ranges.

Limestone and shell deposits are abundant in the San Francisco Bay area, and many of them have been developed to serve regional and local markets. The earliest commercial developments were for lime, beginning about 1850 at the Olcma deposit in Marin County and in 1851 at the Cowell Home Ranch deposits in Santa Cruz County. Some lime also may have been produced in 1851 from the Lime Ridge deposits, Contra Costa County. The first cement (hydraulic) was produced in 1860 from limestone near Benicia, Solano County. Portland cement was first manufactured in 1902 at Cement, Solano County, and in 1903 at Napa Junction, Napa County. The strong demand for lime coupled with excessive land transportation costs were responsible for the opening of many small, and often impure, deposits of limestone in the late nineteenth and early twentieth centuries. A number of deposits also were opened in the 1920s and early 1930s to meet the sudden expanded demand for agricultural limestone. For additional historical data see Bowen, 1951. More recently, a number of quarries were established in cherty limestone to supply structural needs such as aggregate and road material. It is emphasized here that many of the deposits, originally operated as local sources of lime and structural and

agricultural materials, are no longer of economic interest. Limestone of potential industrial value appears to be limited to the crystalline limestone of Santa Cruz County and the shells of San Francisco Bay. However, with selective quarrying and beneficiation, the limestone of the Franciscan Formation may also have industrial potential.

Geologically, the oldest limestone in the San Francisco Bay area is part of a metamorphic rock unit similar to the Sur Series of the Santa Lucia Range to the south. Most of the limestone is coarse crystalline and high in calcium, although some is notably siliceous and some is locally magnesian. Substantial but undetermined limestone reserves exist in Santa Cruz County, and small occurrences are known in Marin and San Mateo Counties. Most of the lime manufactured in the Bay area was made from the crystalline limestone of Santa Cruz County.

Even more widespread is the Cretaceous limestone of the Franciscan Formation. Limestone of the Franciscan has been informally designated the Calera and Laytonville types—the Calera-type being light to dark gray and the Laytonville-type being pink to red (Bailey *et al.*, 1964, p. 68–77; Garrison and Bailey, 1967, p. B94-B100). The former is much more common than the latter. Both types of limestone are fine grained, thin bedded and highly fossiliferous (Foraminifera, nannoplankton). Large reserves of the Franciscan limestone are available in San Mateo and Santa Clara Counties and minor deposits are known in Marin, Sonoma, and Alameda Counties. However, because abundant thin interbeds and lenses of chert are almost always present, most of the limestone deposits are of value solely as sources of crushed stone. The one great exception is the Permanente deposit which, as a result of selective quarrying and recent beneficiation, has provided raw materials for a major cement plant since 1939. A few other limestone deposits may be large enough to be amenable to beneficiation and consequently may be of potential industrial value.

Quaternary carbonate deposits of two types have also been of considerable importance. Deposits associated with springs have yielded large quantities of travertine, calcareous tufa, and caliche for cement

manufacture in Contra Costa and Solano Counties, but reserves are largely depleted. Some of the surficial carbonate deposits, however, may be of value for ornamental uses. Quaternary shell deposits are of greater future value, with apparent large reserves existing in southern San Francisco Bay. The shells are largely associated with soft bay mud which is used with the shells for cement manufacture* or is easily washed from the shells used for various agricultural and industrial purposes. Similar but smaller shell deposits may also exist in the other bays and estuaries of the central region.

A variety of other limestone deposits, ranging in age from Late Jurassic(?) to Pleistocene, have been used or considered as sources of carbonate rock. Most of these are too impure or too small to be of future interest other than as local sources of crushed rock.

Total production of limestone and shells in the central Coast Ranges region through 1968 is estimated to be 145 million tons. About 80% was used for cement, 4% for lime, 1 to 2% for livestock feed and soil conditioning, and the remainder for aggregate, riprap, road base, and other construction purposes. The principal production has come from the following counties, listed in approximate order of decreasing production: Santa Clara, Santa Cruz, San Mateo, Contra Costa, Alameda, Solano, and Napa. Minor amounts of limestone have also been produced in Marin, Sonoma, and San Joaquin Counties.

The limestone deposits of the central Coast Ranges region are shown on plate 1B and are discussed below in alphabetical order within each district. The districts of the region are listed in geographic order from north to south.

HEALDSBURG DISTRICT (B-1)

This district, which covers Sonoma County and part of Napa County, is relatively unimportant as a future limestone-producing area. Small amounts of limestone were quarried intermittently as sources of lime from the Black Ranch and Pope Valley deposits, and from an unnamed deposit near Geyserville, between 1880 and 1937. Other deposits remain undeveloped. The only recent activity is at Petaluma, where shells, dredged from San Francisco Bay by Pioneer Shell Company, are processed for livestock and agricultural uses (see San Francisco Bay Shell deposits under San Francisco Bay district).

Black Ranch deposit. Location: Approx. N $\frac{1}{2}$ sec. 30, T. 11 N., R. 9 W. (proj.), M.D., 5 miles north of Geyserville; Kelseyville 15-minute quadrangle. Ownership: Hollis M. Black, 28225 River Road, Cloverdale (1962).

This deposit has been worked intermittently as a source of lime rock from 1884 to 1907 and again in

1937. According to Aubury (1906, p. 93), "It was first opened in 1884, and reopened in April, 1901" by the Sonoma County Lime Company. The same company worked the deposit again in 1906-1907. J. F. Bishop of Santa Rosa apparently was the operator in 1937.

The Black Ranch deposit consists of a single bold outcrop of limestone 150 feet long by a maximum of 70 feet wide with a relief of about 50 feet. It lies between the dirt access road and a west tributary to Little Sulphur Creek. The limestone projects from a structurally disturbed terrain mainly consisting of graywacke, chert, schist, greenstone, and other Franciscan-like rocks. Faint bedding(?) in the limestone appears to dip steeply to the east. The limestone is fine to medium crystalline, dense, brownish gray sometimes mottled with white, with no visible impurities. Two typical grab-samples (BR-1 mottled with white) were analyzed by Lydia Lofgren in 1962 and show the following chemistry:

Sample	CaO	MgO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	P ₂ O ₅	Ign. loss
BR-1.....	55.00%	0.43%	0.80%	0.12%	0.07%	0.04%	43.08%
BR-2.....	54.50	1.19	0.90	0.13	0.14	0.02	43.22

Development is limited to a small hillside quarry on the north side of the deposit. Not more than a few thousand tons of limestone were quarried, and this was hauled 300 feet east to a vertical (continuous) stone kiln of 50 barrels per day capacity. Reserves are small; probably not more than 20,000 to 30,000 tons of limestone.

Other references: Ireland (?), 1888, p. 633; Crawford, 1894, p. 396; Bradley, 1916, p. 323; Logon, 1947, p. 333; Honke and Ver Planck, 1950, p. 95.

Healdsburg Marble Company deposit. Location: NE $\frac{1}{4}$ sec. 2, T. 9 N., R. 12 W., M.D., 7 miles west-southwest of Skaggs Springs and 15 miles west of Healdsburg; Tombs Creek 7 $\frac{1}{2}$ -minute quadrangle. Ownership: Not determined.

Many years ago, a company by this name located claims on a fine-grained, "red, white, and cream colored" limestone in secs. 1 and 2 (Bradley, 1916, p. 323). This undoubtedly is the same as, or includes, the reddish Franciscan limestone at the southeast end of Shoeheart Ridge in NE $\frac{1}{4}$ sec. 2, E. H. Bailey (oral communication, 1962) reported the limestone to be thin bedded and traceable for about 1,000 feet in a westerly direction. It is sandwiched between greenstone on the south and sandstone on the north. The limestone sequence is about 7 feet thick in a tributary to House Creek, but it is a little thicker to the west. No chemical analyses are available, but the limestone may be impure (Honke and Ver Planck, 1950, p. 95). Because of its inaccessibility and small reserves, the deposit is undeveloped and does not seem to be of economic interest.

Other reference: Logon, 1947, p. 333.

Kohlman (Coleman) Gulch deposit. Location: Sec. 13, T. 8 N., R. 13 W., M.D., about 1 $\frac{1}{2}$ miles north

* Production of shells for cement manufacture ceased in late 1970. See footnotes under San Francisco Bay Shell deposits.

of Fort Ross; Plantation 7½-minute quadrangle. Ownership: Not determined.

"Extensive deposits of pulverulent limestone" were noted by Watts (1893, p. 463) in Coleman Gulch. Logan (1947, p. 334) corrected the spelling of "Coleman" to "Kohlman" and stated that "only meager evidence of limestone was found." Current topographic maps now show the name of the stream to be Kolmer Gulch. There is no development of the deposit.

Other reference: Honke and Ver Planck, 1950, p. 95.

Pioneer Shell Company. The company operates a plant at 100 East "D" Street, Petaluma, where oyster shells from San Francisco Bay are processed. (For description see San Francisco Bay Shell deposits, San Francisco Bay district.)

Pope Valley deposit. Location: Vicinity of sec. 32 (E), T. 10 N., R. 5 W., M.D., about 11 miles north of St. Helena; St. Helena 15-minute quadrangle. Ownership: Not determined.

According to Crawford (1896, p. 629), lime was made in two kilns in Pope Valley during the 1890s. Reportedly, only small quantities of lime were made although "two kilns are in constant use". The source of limestone is not known but could have been thin beds or lenses of limestone that commonly occur in the Knoxville Formation or overlying Lower Cretaceous rocks of Pope Valley. An old lime kiln in or near sec. 32 (Dow and Thayer, 1946, p. 23) may relate to the above. Knoxville and associated strata are exposed along the north margin of Pope Valley and near sec. 32.

Other reference: Bradley, 1916, p. 271.

Purviance Ranch deposit. Location: Possibly sec. 23 or 24, T. 9 N., R. 10 W., M.D.; Healdsburg 15-minute quadrangle. Ownership: Not determined.

Small outcrops of limestone have been reported 3½ miles west of Healdsburg on the Purviance Ranch. Apparently there is no development of this deposit, although C. A. Perry had an option on it (Lazure, 1926, p. 336). The deposit was not located during the present study. A chemical analysis of the limestone, made in 1906 by Thomas Price and Son, is partially as follows: 93.45% CaCO₃, 1.22% MgCO₃, 1.13% FeCO₃, 1.96% Al₂O₃, and 1.59% SiO₂. The limestone lies in an area underlain by the Franciscan Formation.

Other references: Lagan, 1947, p. 334; Honke and Ver Planck, 1950, p. 95.

Unnamed deposit (near Geyserville). Location: Near E¼ cor. sec. 14, T. 10 N., R. 9 W., M.D., 4½ miles east of Geyserville; Healdsburg 15-minute quadrangle. Ownership: Not determined.

This deposit is developed near an old marble quarry and kiln. It is described by Gealey (1951, p. 46, plate 1): "The marble is gray and finely crystalline, but in scattered patches some calcite crystals reach a length of as much as 2 inches. The material is in metamorphosed Franciscan limestone. Lime was first burned

here about 1880. The body is far too small to be of economic importance today." The deposit may be the same one referred to by Irelan (1888, p. 633) or Crawford (1894, p. 396).

NORTH BAY DISTRICT (B-2)

This district includes all of the deposits in Marin and Solano Counties and one deposit in southern Napa County (plate 1B). Not only have these deposits contributed substantially to the early economy of the San Francisco Bay area, they have also contributed richly to its history. Possibly the first limestone deposit worked commercially in the Coast Ranges of California is the tiny Olema deposit, operated about 1850–1852. The Inverness Park and Cement Hill deposits also were very early sources of lime rock. About 1860, California's first hydraulic cement plant was established at Benicia. It used shells or impure limestone from local deposits until it was shut down around 1890. One of the earliest Portland cement plants in California was established at the Cement Hill deposit in 1902. Here, travertine was quarried as the principal raw material. The next year, impure shelly limestone was developed as a source of cement rock at the Napa Junction deposits. Some of these deposits, along with the Tolenas Springs deposit, also yielded limestone for terrazzo, decorative stone, and flux.

Only the Tolenas Springs deposit is now active. It presently is operated on a small scale, yielding travertine and onyx marble for terrazzo.

The deposits are geologically varied, consisting of crystalline limestone of pre-Cretaceous age, dense limestone of the Franciscan Formation, impure limestone (both fine grained and bioclastic) of late Mesozoic and early Tertiary age, and shell and surficial carbonate deposits of Quaternary age.

The deposits of the North Bay district seem to offer little significant commercial potential, except for deposits useful as a source of decorative and crushed rock. Late Quaternary shell accumulations, such as that found in Tomales Bay (see Tomales Bay shell deposit) may provide additional economic possibilities.

Bender deposit. Location: Approx. sec. 21, T. 3 N., R. 9 W. (proj.), M.D., 1 mile south-southeast of Inverness, Marin County; Point Reyes 15-minute quadrangle. Ownership: E. A. Bender, Inverness (1962).

Several small bodies of crystalline limestone associated with biotite schist and intruded by quartz diorite are reported by the owner to occur in a small canyon that drains the northeast flank of Point Reyes Hill. The limestone is situated ½ to ¼ of a mile inland from Willow Point on Tomales Bay. It is similar to the metamorphosed Sur Series limestone of the southern Coast Ranges, being coarse crystalline, white, and sparsely flecked with graphite flakes. Scheelite crystals up to half an inch occur in the limestone, which

stimulated tungsten exploration in the early 1950s (Ver Planck, 1955, p. 260, 265–266). According to the owner, none of the limestone bodies shows a thickness of more than 25 feet. Because of small reserves and its intimate association with schist and granitic rock, the limestone is not believed to be of economic interest.

Benicia Cement Works deposit. Location: Probably SE¼ sec. 34, T. 3 N., R. 3 W., M.D., in Benicia; Benicia 7½-minute quadrangle. Ownership: Not determined.

California's first cement plant was established at Benicia about 1860 to manufacture "hydraulic" cement. The cement works, which had a productive capacity of about 100 barrels of cement per day, was operated intermittently and produced only modest amounts of cement. After approximately 30 years of intermittent production, the works was abandoned. Total production of cement is not recorded in the literature although Williams (1885, p. 675) reports the largest production was in 1872, when 25,500 barrels of cement were made. The cement was used in various construction projects, including a seawall in San Francisco Harbor and the San Francisco City Hall, and in the manufacture of drainage and water pipe. Remnants of an old kiln along the Benicia waterfront south of Eye Street between 8th and 9th Streets still exist and very likely are the remains of the Benicia Cement Works.

The source of "hydraulic" limestone seems uncertain, and there may have been more than one quarry area or deposit. The limestone source has been variously reported to be in the hills behind Benicia (Whitney, 1865, p. 101; Browne, 1868, p. 245), 1 mile south of Vallejo (Williams, 1883, p. 463), and in sec. 33 within the Benicia town limits (Aubury, 1906, p. 185). The nature of the raw material also is unclear. Whitney (1865, p. 101) states that the "hydraulic limestone" is associated with "beds of passage" between "sandstones and shales" (veins filling a fault or fracture?). A description of the material is given by Browne (1868, p. 245) who reports two grades of hydraulic limestone which he describes as being "of a dark yellowish color, speckled with black, tolerably soft; breaks with a dull, earthy fracture, without any appearance of crystallization." Exactly what rock type or units are represented has not been determined. The principal carbonate materials found near the old kiln are part of an upper Pleistocene marine unit (Weaver, 1949, p. 52). Along the waterfront, in a cove northwest of the kiln, this unit consists mainly of bedded mud, shells, and sand of estuarine origin. Five to ten feet of the unit are composed principally of oyster shells similar to *Ostrea lurida* Carpenter. This is overlain by about 20 feet of mudstone with occasional shelly streaks. About 5 feet of impure carbonate beds of variable character (shells, sand, mud, and possibly secondary calcite) and uncertain origin overlie the mudstone (Oliver E. Bowen, 1964, oral communication). Al-

though these carbonate rocks would seem to be the logical source for the Benicia cement, Whitney refers to the oyster beds (1865, p. 102) but does not relate them to cement manufacture. Another possible source is indicated by calcareous shale and argillaceous limestone fragments found in and about the kiln (Oliver E. Bowen, 1964, oral communication). Similar material commonly occurs in the Paleocene and Cretaceous units exposed in the vicinity of Benicia.

Other references: Irellan, 1888, p. 632; Crawford, 1894, p. 381; Logan, 1947, p. 333.

Cement Hill deposits. Location: Secs. 5, 7, and 8; T. 5 N., R. 1 W., M.D., 3 to 4 miles northeast of Fairfield; Mount Vaca and Vacaville 15-minute quadrangles. Ownership: Mineral rights—Ideal Cement Company, 420 Ideal Cement Building, Denver, Colorado 80202; surface rights—E.N. Tooby, Fairfield (1962).

Travertine and related surficial carbonate deposits on Cement Hill were first developed prior to 1865 for use as lime rock and ornamental stone (Whitney, 1865, p. 104). The rock was extensively used as an ornamental material known as "Suisun marble". As a lime rock, the travertine was burned in a vertical kiln located just south of E¼ cor. sec. 7. Remains of the kiln still stand. For some years prior to 1900, the travertine was also obtained from Dicky's quarry for use as flux at ASARCO's Selby smelter (Crawford, 1894, p. 395). Some macadam also was produced. Probably the bulk of the carbonate rock produced was used to manufacture portland cement.

The first cement mill was constructed by Pacific Portland Cement Company (predecessor to Ideal Cement Company) in 1902 at the foot of Cement Hill, 700 feet north of SW cor. sec. 8. The plant was expanded in 1903 and 1905, reaching a capacity of 2,500 barrels of cement per day (Bradley, 1916, p. 303). According to Huguenin and Costello (1920, p. 243), this plant was "completely wrecked" shortly before 1920. In 1907, another cement mill was constructed 2,000 feet to the southeast in sec. 17. Capacity of the second mill was 3,500 barrels per day. Prior to 1910, the carbonate raw material came from the Cement Hill deposits. After 1910, however, most of the limestone was imported by rail from Cool, El Dorado County. The cement plant was closed and dismantled in 1927.

Following the cement operation, travertine from Cement Hill was quarried intermittently for ornamental and terrazzo uses. P. Grassi and Company (1927, 1935–36) and United Quarries, Inc., (1939–42) were the operators. It is reported that Kasser (?) and Ball and the Morrison-Knudsen Company quarried large amounts of travertine and underlying sandstone in the early 1940s to construct airstrips at Travis Air Force Base.

The Cement Hill deposits consist of travertine, calcareous tufa, and related calcareous materials. The carbonate rocks form numerous surficial deposits on

the west, south, and southeast sides of the hill. The deposits probably formed from spring water during Quaternary time, although only a few small springs were noted in the area. However, brecciated sandstone and conglomerate (Domengine and Chico Formations, Weaver, 1949) cemented with travertine suggest that fault-associated springs may have been more prevalent in the past. Travertine is the principal carbonate material remaining, although little can be said of the nature of the material quarried.

Much of the travertine in the quarry areas is medium to coarse crystalline, fairly dense, distinctly banded, and nearly white to yellowish brown. It appears to have formed mainly as near-surface fracture fillings. Elsewhere, particularly in SE $\frac{1}{4}$ sec. 8, the travertine is fine crystalline, usually amber to honey brown, thinly banded, and somewhat porous (vuggy). This variety seems to form at the ground surface. Associated with the travertine are other carbonate materials, including the softer calcareous tufa and caliche, which appear to be somewhat impure. Analyses of the pure travertine (Eckel, 1913, p. 121) show that the material consists mainly of calcium carbonate. Some is also associated with brecciated sandstone and conglomerate. The deposit is a sort of stockwork, grading downward from relatively pure travertine into fractured country rocks having vein fillings of calcium carbonate (Goodyear, 1890, p. 670).

Reserves of carbonate rock are difficult to estimate because deposits are scattered over sec. 8 and adjacent parts of sec. 7 and SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 5. The largest deposit probably was the one located just south of NW cor. sec. 8, where it covers an area 1,700 by 700 feet. A hillside quarry 1,100 by 700 feet with a maximum face of 200 feet has nearly exhausted the deposit. Judging from the depth of the quarry (visited April 1962), it is estimated that the deposit was at least 60 to 70 feet in maximum thickness. In S $\frac{1}{2}$ sec. 8 another extensive deposit covers a triangular area half a mile long by a maximum of 1,800 feet wide. Sandstone exposed in a series of broad, shallow benchcuts indicates the travertine to be no more than 15 to 20 feet thick. This area was worked most recently, probably for construction materials used at Travis Air Force Base.

A number of smaller deposits, some undeveloped, lie on the southeast, southwest, and west slopes of Cement Hill. The most impressive of these is a thin, narrow body several hundred feet long situated 1,200 feet east-southeast of center sec. 8. Thinly banded, yellowish-brown, fine-grained, vuggy travertine of rather pleasing appearance constitutes the deposit. Such material may be useful as terrazzo and for other ornamental purposes. Reserves may be in the order of 10,000 tons. Larger reserves exist elsewhere on Cement Hill, but the travertine does not appear to have as much ornamental value.

Deming's Point deposit. Location: Approx. sec. 16, T. 3 N., R. 3 W., M.D., 2 miles east of Vallejo; Benicia 7 $\frac{1}{2}$ -minute quadrangle. Ownership: Not determined.

"A large outcrop of rock suitable for making cement" is reported by Crawford (1894, p. 381). There has been no known development. The area is underlain by the Chico Formation of Late Cretaceous age (Weaver, 1949, plate 15).

Inverness Park (Lockhart Traet, Point Reyes, Tomales Bay, Trout Farm) deposits. Location: Near SE $\frac{1}{4}$ sec. 34, T. 3 N., R. 9 W. (proj.), M.D., 1 $\frac{1}{2}$ miles west of Point Reyes Station; Point Reyes 15-minute quadrangle. Ownership: J. W. Lockhart, Inverness Park (1962).

Coarse-crystalline, white to brown-stained limestone similar to the Sur Series limestone is exposed as scattered outcrops on the Lockhart Ranch near Drakes Summit Road, 3,000 feet west of Inverness Park. Reportedly, the limestone can be traced by means of detached outcrops and float for nearly half a mile northwest to a point not more than 200 yards southeast of Drakes Summit (Ver Planck, 1955, p. 259). The presence of granitic soil between the detached outcrops strongly indicates that the deposit consists of small discontinuous masses of limestone. According to Alan J. Galloway (unpublished report), the limestone covers an area of about 30 acres and the largest exposure is about 40 feet long by 20 feet high. Additional limestone is exposed in Haggerty Gulch about a quarter mile to the east of the summit exposures. Here, coarse-crystalline white limestone is interbedded with schist and cut by dikes of pegmatite and quartz diorite.

A number of limestone samples have been collected and analyzed over the years and these are listed in table 2. Samples 1-6 probably indicate the best grade of limestone available. Some of the limestone, however, is locally siliceous or iron stained (sample 7).

The Inverness Park deposits were developed in a limited way many years ago. A small quarry and several test pits are situated just northwest of Drakes Summit Road on the Lockhart property. Another quarry is reported at the "Trout Farm" locality (Eckel, 1933, p. 353) which is believed to be in the canyon at the north end of the deposits. Apparently the limestone was used mainly as a source of lime. Two small kilns are reported by Ver Planck (1955, p. 259) close to Drakes Summit Road within 100 yards of Sir Francis Drake Highway. These kilns apparently were operated at least as early as 1856 (Galloway, unpublished report) and were last used around the turn of the century (Eckel, 1933, p. 353). Production was small, although no official records exist. Potential of the limestone near Inverness Park seems quite limited, as limestone reserves appear to be small and distributed among a number of small, scattered bodies.

Other references: Browne, 1868, p. 243; Watts, 1890, p. 669 and 1893, p. 191; Aubury, 1906, p. 108, 185-189; Laizure, 1927, p. 205-208, 210; Lagan, 1947, p. 332; Weaver, 1949, p. 88, pl. 5, 7.

Other references: Anderson, 1899, p. 131; Lagan, 1947, p. 251; Weaver, 1949, p. 88, plate 9; Galloway, 1962, p. 396, plate 26.

Table 2. Chemical analyses of limestone from Morin County.

Sam- ple	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	CaCO ₃	MgO	MgCO ₃	P ₂ O ₅	Ign. loss
1	1.66%	0.44%	0.20%	ND	96.60%	ND	0.75%	ND	ND
2	2.26	0.55	0.25	ND	95.48	ND	1.10	ND	ND
3	2.23	0.76	incl.	53.80%	96.00	0.35%	ND	ND	42.70%
4	1.30	0.30	incl.	54.32	97.00	1.25	ND	ND	42.68
5	1.98	0.32	0.09	53.95	ND	0.38	ND	~0.03%	ND
6	2.65	0.39	0.34	53.50	ND	0.85	ND	0.07	42.20
7	10.81	5.75	1.61	43.25	ND	0.80	ND	0.21	ND
8	1.10	0.68	incl.	54.80	97.80	ND	tr	ND	43.20
9	1.90	0.76	0.20	ND	96.74	0.33	ND	ND	ND
10	2.35	0.51	0.31	53.89	ND	0.18	ND	0.07	ND
11	1.69	0.22	0.40	54.15	ND	0.29	ND	0.14	ND

ND = Not determined.

incl. = included with Al₂O₃.

tr = trace

Samples 1-7 are crystalline limestone similar to the Sur Series of Monterey County

Sample 1 from old quarry near "Trout Farm" (North of Lockhart Ranch).

Samples 2-3 and 5-7 from Lockhart Ranch

Sample 4 from near Inverness Park.

Samples 8-11 are Franciscan Formation limestone from Olema deposit

Analyses 1-4 and 8-9 published in Eckel (1933, tables 1 and 2).

Analyses 5-6 and 10-11 made by Abbot A. Hanks, Inc., 1956

Analysis 7 made by Lydia Lofgren, Calif. Division of Mines and Geology, 1962

Napa Junction deposits. Location: E $\frac{1}{2}$ sec. 24, T. 4 N., R. 4 W., and W $\frac{1}{4}$ sec. 19, T. 4 N., R. 3 W., M.D., 1 mile south of Napa Junction and 5 miles north of Vallejo; Cordelia 7 $\frac{1}{2}$ -minute quadrangle. Ownership: Principally Basalt Rock Company, 8th and River Streets, Napa (1962).

Impure limestone and associated clay were used to make cement from 1903 to 1918 by Standard Portland Cement Company. The company reportedly ceased operation of their Napa Junction plant in September 1918, apparently because most of the better quality limestone was used up. The Napa Junction deposits are not known to have been worked since 1918.

The limestone is exposed as low outcrops in two areas separated by alluvium. The north, or main, deposit occupies a low, west-plunging ridge on which are located a series of elongate pits. Because of thick soil, exposures are limited mainly to the steep faces of the pits. Here, the deposit consists of 50 to 100 feet of crudely bedded, bioclastic limestone and related impure carbonate rocks that strike about N 75° E and dip 35° N. Underlying the clastic beds at the base of the exposed south face of the largest pit are beds of shale with small lenses and concretions of fine-grained, blue-black, impure limestone. It seems apparent that the upper beds served as the principal source of limestone and clay. These range in composition from nearly pure bioclastic limestone, with only scattered noncarbonate fragments, to a fossiliferous mudstone containing large amounts of mudstone (tuffaceous?) pebbles and fossil debris. Color of the rocks varies from greenish gray to yellowish brown and grain size ranges from fine sand to gravel. Most of the carbonate material appears to be shell and algal debris—probably derived from a near-shore reef. The age of the

limestone could not be determined although Weaver (1949, plate 15) shows it to be part of the Eocene Domingine Formation. In contrast, however, Weaver indicates similar limestone half a mile to the south to be part of an undivided sequence of Late Jurassic or Early Cretaceous age.

At the south deposit the carbonate rocks are similar to those of the main area, but they may be less pure and finer grained. Certainly the south exposures are less extensive, covering a low rise perhaps 300 to 400 feet in diameter. The rocks are not well bedded here although one bed showed a dip of 70° W. A third and even smaller outcrop is exposed in a small pit 1,000 feet northwest of the main outcrop.

Because the limestone of the three areas show common characteristics, they are no doubt of common origin and probably of the same formation. However, the deposits probably are not contiguous, as there is evidence of faulting and brecciation in the main and south areas.

Chemical analyses of the limestone were made many years ago and are shown in table 3. According to Eckel (1913, p. 121-122), the deposit contained two grades of limestone that ran 60 to 65% and 85 to 90% calcium carbonate. It is obvious that very little "high-grade" limestone remains in the deposit although low-grade limestone and related calcareous beds may be extensive, particularly in the main area. Reserves are not known; but, even if large, the deposit appears to be too impure for cement manufacture and other uses. Most of the reserves are expected to be north of and down dip from the main quarry area.

Table 3. Chemical analyses of limestone from Napa Junction deposits, Napa County (from Eckel, 1913, p. 122).

Sample	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaCO ₃	MgCO ₃
High-lime rock					
No. 1	6.63%	3.61%	1.26%	85.17%	1.83%
No. 2	7.12	2.36	1.16	87.70	0.84
Low-lime rock					
No. 1	20.87	10.50	3.50	62.76	1.48
No. 2	20.23	8.68	3.11	65.23	1.72

Development of the limestone was mainly near the E $\frac{1}{4}$ cor. sec. 24 along the north side of the ridge where three linear pits extend continuously over an area 1,700 feet by 200 to 400 feet. Excavation apparently extended deeper than the present pit, which is as deep as 40 feet and has been partly filled with debris and slope wash. Smaller pits lie west and north of the main quarries. In the south area, the pit is about 200 by 300 feet in area and is more than 25 feet deep. Most of the pits were worked below the water table and contain ponded water. Based on the observable sizes of the pits (April 1962), it is estimated that at least 1.5 million tons of limestone and associated clay was produced during the 15 years of operation. The raw materials were hauled in small dump cars by rail to the cement mill located immediately north of the main quarry.

There is some indication that high-grade limestone from Santa Cruz was used to "sweeten" the raw material mix. The cement mill utilized the dry method, employing two large rotary kilns and 10 small rotary kilns with a total capacity of 2,500 barrels of cement per day.

Other references: Bradley, 1916, p. 262-268; Huguenin and Castella, 1920, p. 158; Eckel, 1933, p. 359-360.

Noren deposit. Location: Near S $\frac{1}{2}$ sec. 35, T. 3 N., R. 9 W. (proj.), M.D., 1 mile southwest of Point Reyes Station; Point Reyes 15-minute quadrangle. Ownership: C. R. Noren, Inverness Park (1962).

A small pendant of metamorphic rock in quartz diorite is situated 1,000 feet south of the intersection of Sir Francis Drake Highway and Bear Valley Road. The pendant consists of coarse-crystalline, white to brown (stained?) limestone and fine-crystalline, gray limestone interbedded with biotite schist similar to that of the Sur Series. The gray limestone is silicified and locally replaced by scheelite, which was prospected to some extent in 1952 (Ver Planck, 1955, p. 260, 266). Another small pendant of limestone is reported half a mile to the southwest in the same creek. From what was seen (April 1962) and reported, the Noren deposit appears to be too small and impure to be of commercial value as a source of limestone.

Olema ("Russian Kilns") deposit. Location: Approx. sec. 28, T. 2 N., R. 8 W. (proj.), M.D., 4 miles southeast of Olema and 6 miles southeast of Point Reyes Station; Mount Tamalpais 15-minute quadrangle. Ownership: Sam Smoot, Petaluma (1955).

The Olema limestone deposit was first developed about 1850 as a source of lime rock. Lime was calcined in three adjacent kilns. According to Treganza (1951, p. 69), the lime kilns probably were operated last in 1852, although it is possible lime could have been burned as late as 1869. Production is believed to have been minor, as no large quarry exists at the deposit. The kilns, which are located on the east bank of Olema Creek immediately below the limestone exposure, were previously believed to have been built and used by the Russians at an early date. However, this theory is fairly well disproved by Treganza (1951), who studied the kilns in detail.

The limestone is confined to a single outcrop about 50 feet wide, 100 to 125 feet long, and 40 to 50 feet high. Approximately 50 feet of strata are present, and these strike N 60° W and dip 55° SW. The deposit consists of thin-bedded Franciscan limestone and minor interbedded chert, which is associated with other Franciscan rocks along the San Andreas fault zone. The limestone typically is light tannish gray, dense, fine grained, and foraminiferal. Chemistry of the limestone is indicated by analyses of samples 8 to 11 in Table 2.

Because no limestone is visible beyond the exposed deposit, it is presumed the limestone deposit is a fault

sliver that does not extend much beyond the outcrop area. Some fragments of similar limestone are reported from two areas 1,000 feet and 2 miles to the southeast in the fault zone (Galloway, unpublished report). At the latter locality there are remnants of another old kiln. Reserves of limestone at the Olema deposit are estimated to be in the order of 10,000 to 15,000 tons.

Other references: Lagan, 1947, p. 251; Ver Planck, 1955, p. 261; Galloway, 1962, p. 395, 398.

Tolenas Springs (California Onyx Marble) deposits. Location: W $\frac{1}{2}$ sec. 2 (proj.), T. 5 N., R. 2 W., M.D., 4 miles north of Fairfield; Mount Vaca 15-minute quadrangle. Ownership: Woods Estate Ranch (1962); operated by Tolenas Quarry Company, 537 Cottonwood Drive, Fairfield (1969).

Travertine and calcareous onyx have been known at Tolenas Springs at least since 1878, when specimens were displayed at the Paris Exhibition. Exactly when the deposits were first worked commercially is not known, but it may have been about the same time (Hanks, 1884, p. 72; Goodyear, 1890, p. 670). The deposits have been worked intermittently on a small scale as a source of ornamental stone and terrazzo materials. The early operators are not known; but the later developers include S. Miletin (1926 and earlier?), P. Grassi and Company and L. Cardini (1928-1936), and Ray McRoberts and Paul Lahmon of Tolenas Quarry Company (since about 1960). Total production is believed to be several thousand tons.

Several small deposits of travertine and onyx lie in the vicinity of Tolenas Springs in NW $\frac{1}{4}$ sec. 2 (proj.). These rest on sandstone—apparently of the Chico Formation. The main deposit is situated at the east end of the group on the south bank of Soda Springs Creek. It covers an area about 400-by-200 feet and may have been 25 feet thick or thicker at one time (Goodyear, 1890, p. 671). The travertine is typically fine grained, tan or brownish, thinly banded, and somewhat porous. The calcareous onyx is microcrystalline to finely fibrous, milky white to pale amber, translucent, semiresinous to waxy, delicately banded, and dense but commonly cavernous (vuggy). The onyx occurs as lenses and irregular fracture fillings in the travertine. Both materials are somewhat fractured and are obtained in small pieces. Similar, but smaller, spring deposits can be traced to the southwest for a quarter of a mile. Another deposit 200 yards to the northwest of the main deposit is shown by Weaver (1949, plate 5), but nothing is known of this.

Development has been sporadic and limited principally to the main deposit. Recent (1962) workings consist of a quarry face 15 feet high and 100 to 150 feet long. By April 1967, small amounts of onyx or travertine had also been produced from pits a quarter of a mile southwest of the main quarry (Oliver E. Bowen, personal communication, 1967). To the west and southwest are two small old quarries, one of which is about 30-by-30 feet with a 10-foot face. In 1962, the

carbonate material was selectively mined, crushed, screened, and sold as terrazzo under the names "Golden Travertino" (travertine) and "California Onyx". Reserves of the two materials are not known although the travertine appears to be more abundant than the onyx.

Other references: Watts, 1890, p. 668; Waring, 1915, p. 162-163, 165; Loizure, 1927, p. 210; Logan, 1947, p. 332.

Tomales Bay Shell deposit. Location: Approx. sec. 5 (proj.), T. 3 N., R. 9 W., M.D., 2 miles north-northwest of Inverness; Inverness 15-minute quadrangle. Ownership: Not determined.

This undeveloped shell deposit is described here to demonstrate that sizable accumulations of shells exist in coastal bays other than San Francisco Bay (see under San Francisco Bay district) and that different exploration methods can be used in combination to delineate submerged shell deposits.

According to C. C. Daetwyler (unpublished report, 1965, p. 56, 184), a shoal area on the northeast side of Tomales Bay is covered with Holocene shells and associated mud at least 7.8 feet thick. The shells are shown to cover an irregular area of more than 100 acres with maximum dimensions of about 4000-by-2000 feet. By combining an acoustic-reflection survey (Sonoprobe) with shallow cores and test borings, Daetwyler (p. 48, 56, 67, 75, 184) was able to determine the surface distribution of the shell accumulation. A description of test boring No. 13 (Daetwyler, p. 184), made in 13 feet of water east of Pebble Beach, shows shells (predominantly *Ostrea lurida* Carpenter) in a silt and clay matrix, with scattered pebbles and angular quartz grains to a depth of 7.8 feet below the present bay bottom. Although 5 to 30% shells are indicated to be present on the bay bottom (Daetwyler, p. 56), the average thickness and percentage of shells present for the entire deposit is unknown. Based on this limited information, roughly 100,000 to 500,000 tons of shell are believed to be present in this shallow deposit.

Using similar exploration methods, Daetwyler (p. 112, 180) also found other shell deposits 1 to 2 miles to the northwest at the base of an older bay mud sequence. Because these older deposits are small and covered by 34 feet of mud, they are not of commercial interest. However, the younger shell deposit may be of economic value because of its shallow depth and the low cost of dredging and washing. On the other hand, various other economic and political factors may tend to conflict with dredging activities.

Other reference: Eckel, 1933, p. 359.

SAN FRANCISCO BAY DISTRICT (B-3)

This district encompasses the deposits in and about San Francisco Bay in Alameda, Contra Costa, San Francisco, and San Mateo Counties and adjacent parts

of San Joaquin and Santa Clara Counties. There is a wide variety of limestone and shell deposits in the district, but no dolomite is known. Because the district encompasses a highly populated and industrialized area, virtually all carbonate occurrences have been examined; and many, including some very small or impure ones, have been worked as sources of limestone.

As many as 14 or 15 deposits have been worked for limestone and shells beginning about 1851. Since then, large amounts of limestone and shells have been produced for cement (San Francisco Bay Shell deposits, Lime Ridge deposits) and for crushed rock uses (Rockaway deposits, Skyline deposits). Limestone and shells have also been used for a variety of other purposes, including lime manufacture, livestock feed, soil conditioning, and decorative uses. In 1968, the San Francisco Bay Shell deposits and the Rockaway deposits were still being used extensively as sources for cement, crushed rock, livestock feed, and soil conditioning.

The carbonate materials are widely distributed in the San Francisco Bay district in a variety of forms. Most important, in terms of both past and future resources, are the shell deposits of southern San Francisco Bay and the thin-bedded chert-associated Cretaceous limestone of the Franciscan Formation in San Mateo County.

The shell deposits, which are largely associated with soft bay mud, reflect population explosions of the native oyster, *Ostrea lurida* Carpenter, during Holocene time. Although impure, these deposits contain extensive reserves at a shallow depth and are easy to dredge. Other deposits may exist outside of the southern arm of the bay, but none of commercial value is known.

The thin-bedded limestone of the Franciscan Formation—commonly referred to as Calera limestone—is also important. Deposits of this relatively impure limestone (usually 20 to 50% chert) are distributed discontinuously along a narrow belt for 11 miles southeast of Rockaway in Pacifica (Walker, 1950b; Darrow, 1963, plate 1). Of at least nine quarries, Rockaway was the only active deposit in 1968. Unless the deposits can be beneficiated, future development will depend on construction and other crushed rock needs.

Quaternary deposits of travertine, calcareous tufa, and other surficial materials have been important in the past (Lime Ridge deposits) but only relatively small reserves remain. Other limestone deposits of pre-Cretaceous to Quaternary age are either too small or too impure to be of future commercial use, except as local sources of crushed rock.

Cahill Ridge deposits. Location: Secs. 2 and 3, T. 5 S., R. 5 W., and secs. 33 and 34, T. 4 S., R. 5 W., M.D., 4 miles southwest of San Mateo; Montara Mountain 7½-minute quadrangle. Ownership: City and County of San Francisco Water Department (1962).

Limestone of the Franciscan Formation is shown as four discontinuous masses extending more than 2 miles northwesterly from SW $\frac{1}{4}$ /SW $\frac{1}{4}$ sec. 2 by Walker (1950b, plate 1). The deposits, which lie on the steep, vegetated slopes of Cahill Ridge, are of difficult access except at the southeast end. There, typically light-gray, fine-grained, dense, high-calcium limestone, associated with thin-bedded chert, is exposed as occasional low outcrops; and there is abundant angular float over an area 400 feet by at least 800 feet. The northwest extent of this mass is obscured by dense vegetation, and limestone reserves could be large. Reserves, estimated solely for the exposed area of the limestone mass, are substantial, amounting to about 20,000 tons of limestone and associated chert per foot of depth.

Because the deposits on Cahill Ridge lie within the drainage area of potable water supplies of San Francisco, development possibilities probably are limited. Nonetheless, the Cahill Ridge deposits may represent important limestone reserves and warrant additional investigation. This view is also supported by Walker (1950b, p. 7-8). The deposits are undeveloped and probably unexplored.

California Aggregates (Royce) deposits. Location: Sec. 11, T. 4 S., R. 6 W. (proj.), M.D., in Pacifica, $\frac{1}{2}$ mile south-southeast of Rockaway Beach settlement; San Mateo 15-minute quadrangle. Ownership: Ken Royce, Inc., 205 S. Linden Avenue, South San Francisco (1955).

Franciscan limestone and interbedded chert are exposed in two quarry areas at the crest of the ridge between Rockaway Beach and Pedro Valley. According to Darrow (1963, p. 12 and plate 2), the limestone occurs as two northwest-trending bodies—each about 700 feet long—which are part of a synclinal sequence of basalt, chert, and other Franciscan rocks. However, the bodies are broken by faulting and show considerable variations in bedding attitudes. At the lower (northwest) quarry, the limestone is mainly dark blue gray, fine crystalline, dense, thinly bedded, and interbedded with some chert. Some northeast dips can be seen in the north face of the quarry, but most of the beds are crushed and disoriented. At the upper (southeast) quarry, the limestone is light and dark gray and occurs in thin sequences with chert and basalt. The light-gray to dove-gray limestone is dense, fine grained, and foraminiferal. The deposit apparently is cut by a northwest-trending fault, as beds on either side differ significantly in attitude.

Only two chemical analyses are available for these deposits. An analysis presented by Walker (1950b, p. 7, table 2) shows 32.23% silica for the quarry-run material and reflects the large amount of chert present with the limestone. The other analysis (Logan, 1947, p. 308) shows 91.7% CaCO₃ and 5.1% SiO₂ for the blue limestone.

The deposits were worked as a source of crushed rock used for road base and concrete aggregate from 1944 to 1952 (Davis, 1955, p. 435-436; Logan, 1947, p. 308). The lower quarry is developed as a trench roughly 1,000 feet by 40 feet with a maximum depth of 60 feet. The upper quarry is 400 to 500 feet in diameter and 65 feet in maximum relief. The west end of the quarry is now used to support a large steel water tank. According to Davis (p. 46), both pits apparently were "mined to their economic limits". Based on quarry sizes, it is estimated that roughly half a million tons of rock were excavated. Limestone reserves are not determinable but probably are small. As chert is so prevalent in the limestone, future development of the deposits appears to be limited to crushed rock uses.

Carnegie deposit. Location: SE $\frac{1}{4}$ sec. 33 and SW $\frac{1}{4}$ sec. 34, T. 3 S., R. 4 E., M.D., $\frac{1}{2}$ mile south of Corral Hollow Road at Carnegie (site) and 9 miles southwest of Tracy; Altamont 7 $\frac{1}{2}$ -minute quadrangle. Ownership: Not determined (1962).

The Carnegie deposit consists of several small vein deposits formed during Quaternary time along the Tesla fault zone. The fault separates Franciscan rocks on the south from the Panoche Formation (Upper Cretaceous) on the north (Hucy, 1948, p. 62 and plate 2). According to Aubury (1906, p. 79), the main deposit consists of a "series of aragonite veins" 3 inches to 3 feet wide which dip 65° NE. The hanging wall consists of crushed shales although "considerable serpentine inclusions" occur with the travertine. This deposit is developed by a quarry face 225 feet long by 40 feet high and by four prospect tunnels.

A quarter of a mile to the east in SW $\frac{1}{4}$ /SW $\frac{1}{4}$ sec. 34, small, irregular veins and masses of travertine are exposed over an area 300 feet by 200 feet. The travertine is white to honey brown, banded, fine to very coarse crystalline, locally vuggy, and somewhat brecciated. These deposits are developed by small prospect cuts and pits in which the veins range in thickness from a few inches to a few feet. Exposures on the ridge to the east may also be travertine. The deposits appear to be too small to be of economic interest.

The only record of production is by the California Lime and Cement Company from 1900 to about 1911. Most of the travertine was used to make lime at the Carnegie Brick and Pottery Company plant. Some limestone also was shipped to Stockton for use in glass making. Minor prospecting east of the main deposit was done more recently, but details are lacking.

Other reference: Clark, 1955, p. 39.

Collins deposit. Location: Sec. 30, T. 2 S., R. 3 E., M.D., 1 or 2 miles southwest of Altamont; Altamont 7 $\frac{1}{2}$ -minute quadrangle. Ownership: Graham Nissen, Livermore (1966).

"A small outcrop of crystallized limestone" is reported by Aubury (1906, p. 64) on the summit of a hill in sec. 30. As shown by Hucy (1948, plate 1), sec. 30

is underlain by sandstone of the Panoche Formation (Upper Cretaceous) which is locally overlain by the Cierbo Formation (Miocene). A fossiliferous zone containing abundant oysters 50-to-150 feet above the base of the Cierbo is mentioned by Huey (1948, p. 41).

According to Ron Hart (personal communication, 1966), the Collins deposit is an impure shelly limestone that caps a small knoll. It lies flat and is exposed through a thickness of about 20 feet and over an area about 100 feet across.

Other references: Lagan, 1947, p. 206; Davis, 1950, p. 343.

Highway One deposit. Location: NW cor. sec. 11 (proj.), T. 4 S., R. 6 W., M.D., in Pacifica, just south of Rockaway Beach; San Mateo 15-minute quadrangle. Ownership: Not determined (1962).

A small body of typical light-gray, fine-grained, thin-bedded limestone of the Franciscan Formation is exposed on a knoll just east of State Highway 1. The limestone contains interbeds of chert and appears to grade locally into altered calcareous tuff(?). The strata, which are exposed over an area about 400 feet in diameter, are complicated by faults and folds. Reserves are estimated to amount to 300,000 tons.

The deposit is developed by a small quarry having an area of 200 feet by 100 feet and a relief of 25 feet. The use of the quarried rock is unknown, as the deposit has been idle for many years. Foundation remnants at the deposit may have been for a crusher and other processing equipment (see Eckel, 1933, p. 354).

Other deposits, either smaller or less pure, lie nearby to the east and southwest (Darrow, 1963, plate 1). As these deposits are situated in a residential area, their future potential as crushed rock sources would seem to be quite limited.

Hilltop deposit. Location: Near center sec. 11, T. 5 S., R. 5 W., M.D., $4\frac{1}{2}$ miles southwest of San Mateo; San Mateo 15-minute quadrangle. Ownership: Granite Rock Company, P. O. Box 151, Watsonville (1964).

This deposit consists of a sequence of Franciscan limestone and chert beds just west of the crest of Cahill Ridge. It is a northwest-trending mass which crops out intermittently over an area 1,200 feet by 100 to 250 feet and is associated with greenstone and vesicular basalt. The latter appears to overlie the limestone. The beds are considerably crushed and broken but appear to dip moderately southwest except at the southeast end where they seem to dip gently northeast. The limestone is light gray to dark blue-gray, dense, fine grained, and thinly bedded. Thin interbeds of dark chert occur throughout the deposit and may constitute as much as 40% of the volume. A chemical analysis of a sample representing a 35-foot-thick section of "blue" rock shows 44.96% CaO, 0.36% MgO, 2.23% Al_2O_3 , 0.58% Fe_2O_3 , and 15.59% SiO_2 (Walker, 1950b, p. 7, table 2). Walker indicates the exposed thickness of limestone to be 55 feet.

Just when development began is not known, but the deposit was last quarried in 1951. In that year, the L. C. Smith Company obtained crushed rock for use in road construction in the city of San Mateo. Two quarry faces were developed—the northwest face being 270 feet by 40 feet and the smaller southeast face 100 feet by 40 feet (Davis, 1955, p. 436). It is estimated that 50,000 to 100,000 tons of rock were excavated. The deposit was acquired about 1963 by the present owner, who drilled several inclined holes to assess potential reserves. Limestone reportedly was encountered to an inclined depth of at least 100 feet in one of the test holes. Reserve figures are not available but probably amount to several hundred thousand tons of rock. The large amount of chert present probably limits the deposit to structural (crushed rock) uses.

Lime Ridge (Cowell) deposits. Location: Secs. 7, 8, 17, and 20 (proj.), T. 1 N., R. 1 W., M.D., 1 to $3\frac{1}{2}$ miles southeast of Concord; Walnut Creek and Clayton $7\frac{1}{2}$ -minute quadrangles. Ownership: Main deposits—Newhall Land and Farming Company, 25 California Street, San Francisco; northwest deposits (sec. 7)—L. R. and M. Ginocchio(?), Antioch, and possibly others (1962).

Surficial deposits of travertine and calcareous tufa on Lime Ridge were utilized extensively in the past for cement, lime, sugar rock, flux, and soil conditioning. Initial development of the deposits may have been by a man named Shreeve who worked the "Mt. Diablo quarries" and burned lime near Pacheco (2 miles west of Concord) in 1851 (Logan, 1947, p. 220). Early production of limestone on Lime Ridge seems to be verified by Crawford (1896, p. 628). As records were not kept prior to 1903, there is little information on early development.

From 1903 to 1915, Henry Cowell Lime Company (since known as Henry Cowell Lime and Cement Company) produced travertine for use in lime manufacture. The limestone was quarried at the main deposits (probably in sec. 17) and shipped first to a kiln in Concord and later to four continuous kilns near the quarry (Davis and Goldman, 1958, p. 527). A cement plant was constructed north of the main deposits in 1907, and portland cement was produced from 1908 to 1946. Travertine and calcareous tufa from sec. 17 (proj.) and clay and sand from nearby deposits were used as basic raw materials in cement manufacture. Plant operations ceased in 1946 because of the loss of rail facilities and the approaching depletion of limestone reserves. The mill equipment was sold in 1952, the main building being used as a warehouse thereafter. Production capacity of the Cowell cement plant was rated at 4,800 barrels of cement per day.

Spreckels Sugar Company also worked the main deposits on Lime Ridge for many years prior to 1915. They quarried travertine south of the Cowell quarries in N $\frac{1}{2}$ sec. 20 (proj.) for use in beet sugar refining and

as a smelting flux at the ASARCO smelter at Selby. The Cowell interests acquired the Spreckels holdings in 1915 (Logan, 1947, p. 221).

The only other known production was by Mount Diablo Lime Marl Company from 1924 to 1927 when calcareous tufa and travertine were quarried from the small northwest deposits in sec. 7 (proj.). The principal production probably came from the quarry just north of Treat Lane. The material was crushed and ground for sale mainly as a soil amendment. Some travertine also was sold to the Mountain Copper Company at Martinez as a flux for smelting (Laizure, 1924, p. 85). L. C. Hopper acquired a lease on the property in September 1926 and may have produced a little limestone (Laizure, 1927, p. 16). Although the northwest deposits have not been utilized as commercial sources of limestone for many years, the carbonate rocks and underlying sandstone half a mile northwest of Treat Lane (N $\frac{1}{2}$ sec. 7) have been excavated in recent years, apparently for fill purposes.

Carbonate rocks are found in two distinct areas on Lime Ridge and are referred to herein as the main and northwest deposits. By far the most extensive are the main deposits, which cover an irregular area centering in sec. 17 (proj.) and extending into SE $\frac{1}{4}$ sec. 8 and N $\frac{1}{2}$ sec. 20. Altogether, these deposits cover close to half a square mile on both sides of Lime Ridge but mainly on the southwest side. The northwest deposits are much smaller, covering 10 acres or less along the crest of Lime Ridge. They consist of three small deposits, the largest lying just north of Treat Lane and half a mile southeast of the other two.

Even though limestone reserves are largely depleted, quarry exposures indicate that the deposits were thicker than 15 to 20 feet in only a few places. The deposits consist of travertine and calcareous tufa deposited surficially in and on sandstone of Eocene age (Domengine Formation to the southeast; Markley Formation to the northwest). Carbonate-rich spring waters emanating during Quaternary time from a northwest-trending fault and associated fractures are believed to have caused formation of the deposits. Deposition of carbonate materials has apparently ceased, except possibly in SE $\frac{1}{4}$ sec. 8 where there is some spring activity.

Travertine appears to be the highest quality carbonate rock present, but its relative abundance is uncertain. It is gray to tan, dense, hard, fine grained, and generally faintly banded and swirled. It is commonly brecciated and recemented with coarse crystalline calcite. The travertine probably ranges from calcitic fracture fillings in sandstone on one hand to calcareous tufa on the other. The calcareous tufa generally overlies the travertine and represents a later or more surficial stage of deposition. The tufa is off white to tan, soft, porous, and crudely stratified. It is somewhat impure and may actually grade into caliche, from which it is difficult to distinguish. Chemical analyses of the various types of carbonate rock are given in

table 4. Aside from artificial cuts, the carbonate materials are poorly exposed and commonly veneered with soil. The hummocky topography and brecciation features indicate that the deposits are broken and complicated by faults and landslides. The geologic features of the Lime Ridge deposits are depicted by Ivan Colburn in his doctoral thesis in geology (1961, Stanford University).

Table 4. Chemical analyses in percent by weight of carbonate rock from Lime Ridge (main deposits), Contra Costa County.

Oxides (dried basis)	Lime Ridge #1	Lime Ridge #2	Lime Ridge #3
Ign. loss (CO ₂ + H ₂ O)	42.25%	43.42%	36.6%
CaO	49.70	54.03	42.8
MgO	0.0	0.51	0.3
SiO ₂	7.20	0.91	13.6
Al ₂ O ₃	0.42	0.19	5.0
Fe ₂ O ₃	0.18	0.15	0.3
Na ₂ O	N.D.	N.D.	0.5
K ₂ O	N.D.	N.D.	0.6
P ₂ O ₅	0.02	0.02	0.01
Total	99.77%	99.23%	99.71%

N.D. = Not done.

Samples collected 11-7-62 by Earl W. Hart and analyzed February and March 1963 by Lydia Lofgren, Division of Mines and Geology

Sample 1—typical calcareous tufa, soft, porous, light tan, from main quarry near Treat Lane, E $\frac{1}{2}$ 7—1N—1W (proj.)

Sample 2—typical travertine; buff to tan, hard, dense, fine grained with some crystalline vein calcite, from quarry in NW $\frac{1}{4}$ SE $\frac{1}{4}$ 17—1N—1W (proj.)

Sample 3—impure calcareous tufa or caliche; light tan, soft, porous, with some sand and rock fragments; from quarry in SW $\frac{1}{4}$ 17—1N—1W (proj.).

Development of the Lime Ridge deposits is quite extensive, and virtually all deposits were worked to some degree. The principal workings center in S $\frac{1}{2}$ sec. 17 where a series of quarries, benches, and pits are developed in an irregular and often merging pattern. Most cuts are shallow but some are as high as 40 to 50 feet and one large benched quarry has a relief of 200 feet. Less extensive workings are found at the main deposits in N $\frac{1}{4}$ sec. 20, N $\frac{1}{2}$ sec. 17, and SE $\frac{1}{4}$ sec. 8. Although the amount of material quarried cannot be determined from the irregular workings, as much as 10 million tons of carbonate rock may have been produced from the main deposits if the cement mill operated even close to capacity. In the northeast area, each of the three deposits is developed by quarries. The deposit near Treat Lane was worked by two quarries, the largest being about 125 feet in diameter and 20 to 30 feet deep. Production here is estimated to have totaled 15,000 to 20,000 tons. Half a mile to the northwest, two deposits 600 feet apart are developed by quarries which may have yielded 10,000 tons of carbonate rock.

Reserves of travertine and related carbonate rock are impossible to estimate but are almost totally confined to the main deposits. At the main deposits, the reserves reportedly were approaching depletion (Davis and Vernon, 1951, p. 567). Calcareous tufa and

other impure carbonate material appear to constitute the bulk of the reserves.

Other references: Aubury, 1906, p. 66; Huguenin and Costello, 1920, p. 51-53, 55; Laizure, 1927, p. 9-12, 15-16.

McLaughlin lithographic stone deposit. Location: SW $\frac{1}{4}$ /SW $\frac{1}{4}$ (?) sec. 35, T. 1 S., R. 2 W., M.D., $3\frac{1}{2}$ miles southwest of Danville; Concord 15-minute quadrangle. Ownership: R. and A. Mueller, Oakland (1950).

Hard, locally siliceous limestone occurs as a 5-foot bed between sandstone and conglomerate, apparently at the head of Cull Canyon. The bed dips 75° SW and can be traced over a length of 570 feet. It was quarried about 1905 by A. Ramage, who exposed a face 25 feet long by 20 feet high (Huguenin and Costello, 1920, p. 23). The stone was tested for lithographic use but was considered unsuitable for that purpose. The deposit may be part of the Mulholland Formation of Pliocene age (Ham, 1952, p. 15, 22, plate 1).

Although the McLaughlin body is not shown on Ham's map (1952, plate 1), other small lenses of fine-grained, blue-gray to white, impure limestone of the Orinda-Mulholland unit are indicated in secs. 11 and 12, T. 2 S., R. 2 W., and sec. 6, T. 2 S., R. 1 W. Ham also shows a lens of white limestone in SW $\frac{1}{4}$ sec. 6 in the Cierbo Formation (Miocene) which he states was tested and found unsuitable for lithographic purposes. Because these limestone lenses are small and impure, their future use would seem to be as local sources of crushed rock. Apparently the blue-gray limestone has been used locally for crushed rock (Ham, 1952, p. 22).

Ron Hart of Exploration Logging, Inc., (personal communication, 1967) reports that a small lens of limestone 200 feet long by 20 feet thick is exposed near the S $\frac{1}{4}$ cor. sec. 35. This deposit had been recently developed by a small quarry.

Other references: Laizure, 1929, p. 433-434; Logan, 1947, p. 206.

Middle Fork deposit. Location: NW $\frac{1}{4}$ sec. 19, T. 4 S., R. 5 W. and NE $\frac{1}{4}$ sec. 24, T. 4 S., R. 6 W., M.D., 2 miles southeast of Pedro Valley (Pacifica); San Mateo 15-minute quadrangle. Ownership: Not determined (1962).

A fairly large, northwest-trending lens of Franciscan limestone is shown along the Middle Fork of San Pedro Creek by Darrow (1963, plate 1). The mass is shown to be nearly a mile long by an average of 300 feet wide in outcrop and to dip 30° to 60° NE. A large tonnage of limestone is indicated by Darrow's map. However, during a brief examination of the north end of the deposit, only scattered limestone outcrops and float were seen over a width of 200 feet. The limestone is typically light and dark gray and contains chert interbeds, as well as redistributed silica.

The paucity of limestone outcrops may indicate that noncarbonate rocks are extensively associated with the limestone, or it may reflect crushing and fracturing because of the proximity of the Pilarcitos fault.

The deposit is totally undeveloped but warrants sufficient prospecting to permit an economic evaluation. If there is any reasonable continuity of limestone between outcrops, accessible reserves for crushed rock uses may amount to several million tons.

Mission Lime Marl (Gallegos) deposit. Location: SW cor. sec. 31, T. 4 S., R. 1 E., M.D., $2\frac{1}{2}$ miles east of Irvington and just east of Mission San Jose; Livermore 15-minute quadrangle. Ownership: Gallegos family, State Highway 9, Mission San Jose (1962).

This is a small surficial deposit of travertine and calcareous tufa that rests on calcareous and fossiliferous sandstone of the Briones Formation (Miocene). It is at least 6 to 8 feet thick. The deposit mainly consists of grayish-brown to tan, hard, vuggy, fine-grained travertine and well-bedded, dirty-white to light-tan, porous, soft, impure, calcareous tufa. Travertine outcrops and float are found sporadically over an area about 300 feet in diameter. At the quarry, the tufa generally overlies the travertine and probably is younger. A chemical analysis of the tufa as reported in Laizure (1929, p. 434), showed 83.1% CaCO₃. The travertine appears to be considerably purer than that.

When examined in 1962, the deposit workings consisted of an irregular quarry (trench) about 100 feet long by 20 to 30 feet wide (average) by 8 feet deep (maximum) and one or two minor test pits. Small amounts of agricultural limestone (tufa?) were produced around 1924 by Mission Lime Marl Company (Laizure, 1924, p. 184). In 1928, W. S. McLean produced some travertine for terrazzo and other ornamental uses. Some of the material also may have been used as a source of lime manufactured at Mission San Jose in the nineteenth century (Irelan, 1888, p. 35). There has been no development in recent years. Based on quarry size, total production is probably less than 1,000 tons. Carbonate rock reserves are undetermined but small.

Other reference: Logan, 1947, p. 206.

Mitchell deposit. Location: SW $\frac{1}{4}$ sec. 32, T. 3 S., R. 4 E., M.D., 12 miles east-southeast of Livermore and 1 mile south of Corral Hollow; Altamont 7 $\frac{1}{2}$ -minute quadrangle. Ownership: Not determined.

A.S. Huey (1948, p. 62) mentions a "lime rock prospect . . . developed in Franciscan rocks about a quarter of a mile south of the Tesla fault." The limestone apparently occurs as thin lenses in shale and chert (Huey, p. 18). The deposit lies a quarter of a mile northeast of Mitchell Ravine.

Oil Canyon (Harkinson) deposit. Location: Secs. 15 and 16, T. 1 N., R. 1 E., M.D., 5 to 6 miles southwest of Antioch; Antioch South 7 $\frac{1}{2}$ -minute quadrangle. Ownership: Not determined.

A 6-foot-thick ledge of impure limestone in Oil Canyon was developed on the land of Colonel Coates prior to 1894, when several tons of rock were shipped to

Antioch for testing as a source of portland cement material (Crawford, 1894, p. 380). It has been described as "an amorphous, compact, bluish-gray, fossiliferous limestone" by Aubury (1906, p. 67). The limestone is probably part of a sequence of Upper Cretaceous rocks in which thin limestone beds, concretions, and shell horizons are not uncommon (Colburn, 1961, p. 11 and plate 1).

Orinda deposit. Location: NE $\frac{1}{4}$ sec. 15 and adjacent parts of secs. 10 and 14, T. 1 S., R. 3 W., M.D., 2 miles south-southeast of Orinda; Concord 15-minute quadrangle. Ownership: Not determined (1962).

A large, northwest-trending body of impure limestone 500 feet wide by half a mile long is reported between the Siesta and Moraga Formations of Pliocene age (Lawson, 1914, p. 22, and Concord map). Where examined in NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 15, the carbonate unit is exposed only as scattered outcrops and probably is interbedded with softer noncarbonate beds. The carbonate rock is pale buff to tan, hard, dense, fine grained, dolomitic, siliceous and locally brecciated, and recemented with calcite. It is likely that the limestone was deposited as a tuffaceous or marly lake bed. The deposit is undeveloped and appears to be useful only as a local source of crushed rock.

Lawson (1914) also shows several small lenses of Siesta and Moraga limestone half a mile to the north in sec. 10 and to the northwest in secs. 5 and 6.

Patterson Pass deposit. Location: Sec. 10, T. 3 S., R. 3 E., M.D., 7 $\frac{1}{2}$ miles east of Livermore; Altamont 7 $\frac{1}{2}$ -minute quadrangle. Ownership: Not determined.

An unimportant travertine prospect of apparent hot spring origin is reported in the center of sec. 3 just north of the Patterson Pass road (Huey, 1948, p. 62).

Picardo Ranch deposits. Location: S $\frac{1}{2}$ sec. 12, T. 4 S., R. 6 W. (proj.), M.D., 1 $\frac{1}{2}$ to 2 miles southeast of Rockaway Beach, Pacifica; San Mateo 15-minute quadrangle. Ownership: Louis Picardo, Pacifica (1962).

Several lenses of Franciscan limestone form a group of deposits that extends two-thirds of a mile northwesterly from the North Fork of San Pedro Creek (Darrow, 1963, plate 1). The largest of these, at the southeast end of the group, is shown to be 800 feet long by 250 to 300 feet wide and is exposed through 200 feet of relief. This body, which was not examined, may contain 1 to 2 million tons of limestone and associated rock.

Just over the ridge to the west is a triangular-shaped body 500 feet long with a maximum width of 300 feet and a relief of 200 feet. The limestone is typical of that of the Franciscan Formation, consisting of thinbedded, fractured, dark-blue-gray limestone and interbedded chert, with lesser amounts of light-dove-gray limestone. Reserves probably are less than half a million tons. Development of this deposit consists of a

small hilltop quarry from which fractured rock was obtained around 1960-61 for use as road base and drain rock in the construction of the nearby high school. The amount of material quarried is unknown. The quarry was idle in May 1962.

Several other small limestone deposits are found nearby one of which may be a westward extension of the developed deposit. There are no chemical analyses or other information on the Picardo Ranch deposits, and only the one quarry is known. Total reserves may be 3 to 4 million tons. Considering the presence of chert with the limestone, it seems likely these deposits will be of value principally as local sources of crushed rock.

Pilarcitos Creek deposits. Location: W $\frac{1}{2}$ sec. 11, T. 5 S., R. 5 W., M.D., 4 miles northeast of Half Moon Bay (town); San Mateo 15-minute quadrangle. Ownership: Not determined (1962).

Typical gray limestone with interbedded chert of the Franciscan Formation is exposed in SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 11 on the northeast bank of Pilarcitos Creek. The dimensions of the body are concealed by dense vegetation. However, the Pilarcitos fault, whose trace approximately coincides with the southeast-flowing creek, probably limits the deposit to the southwest. The deposit is developed by a small quarry from which crushed rock reportedly was obtained more than 20 years ago for local road use.

Less than half a mile to the south, Pilarcitos Creek veers southwestward and crosses scattered outcrops of impure crystalline limestone similar to the Sur Series. Although Lawson (1914, map) shows the limestone as a single northwest-trending mass half a mile long on the southwest side of the Pilarcitos fault, he (Lawson, p. 4 and 22) indicates the deposit to be impure (magnesia, silica) and small ("limited to a few acres"). Heavy vegetation covers much of the deposit area. Small crystalline limestone deposits of similar type are also reported along the ridge top 1 $\frac{1}{4}$ miles to the west-northwest (Elmo Adams, 1962, oral communication). The limestone outcrops southwest of the fault probably represent small pendants in quartz diorite. They are probably too small and impure to be of economic value.

Pleasanton (Pleasanton Lime and Cement Company) deposit. Location: NW $\frac{1}{4}$ sec. 4 and NE $\frac{1}{4}$ sec. 5, T. 4 S., R. 1 E. (proj.), M.D., 2 $\frac{1}{2}$ miles south of Pleasanton; Livermore 15-minute quadrangle. Ownership: Herman Koopman, Route 1, Box 198, Pleasanton (1962).

Small deposits of grayish-tan, well-indurated, sandy coquina lenses interbedded with fossiliferous, massive sandstone of the Briones formation (Miocene) are boldly exposed for half a mile southeast of the railroad cut near the north boundary of sec. 5. The resistant sandstone-coquina unit is several hundred feet thick and dips 70° to 80° SW. The coquina occurs in this unit as scattered lenses as much as 40 feet thick. Very local-

ly, the coquina approaches pure limestone in composition; but it is generally quite sandy, grading into fossiliferous (calcareous) sandstone. A sample of typical sandy coquina from the small quarry was analyzed by Matti Tavela of the Division of Mines and Geology in August 1963 and showed the following content: 36.5% CaO, 0.78% MgO, 23.0% SiO₂, 3.7% Al₂O₃, 0.78% Fe₂O₃, 0.10% P₂O₅. Although total reserves of impure coquina may aggregate several million tons, good quality limestone is practically nonexistent.

The Pleasanton deposit was worked around 1917 by Pleasanton Lime and Cement Company as a source of agricultural lime. Sandy coquina was obtained in NW¼ NW¼ sec. 4 from a narrow hillside quarry where a face 60 feet long by a maximum of 30 feet high was worked. The limestone was hauled via narrow-gauge rail to a nearby plant and burned in two oil-fired kilns. At the quarry, an adit (now caved) reportedly was driven 50 feet northeast to explore the deposit. Not more than a few thousand tons of limestone was produced.

References: Huguenin and Costello, 1920, p. 22; Laizure, 1929, p. 434; Lagan, 1947, p. 206; Hall, 1958, map.

Rockaway (Calera Hill) deposit. Location: Approx. NW¼ SW¼ sec. 2 (proj.), T. 4 S., R. 6 W., M.D., in Pacifica just north of Rockaway Beach; San Mateo 15-minute quadrangle. Ownership: Ideal Cement Company, 420 Ideal Cement Building, Denver, Colorado 80202; leased by Rhodes-Jamieson, P. O. Box 118, Oakland (1970).

The Rockaway deposit is a large mass of Franciscan limestone situated west of State Highway 1, where it forms a resistant prominence known as "Calera Hill". It has yielded large amounts of limestone and associated chert for use as aggregate and other crushed rock products (Davis, 1955, p. 436; Logan, 1947, p. 308; Huguenin and Costello, 1920, p. 178). The limestone also may have been used as a source of lime, because the remains of some kilns are reported (Eckel, 1933, p. 354). The earliest record of production is for E. B. and A. L. Stone Company, who operated a quarry from 1910 to April 1919. Apparently, the deposit then lay idle until 1942 but has been active ever since. The other operators include Rockaway Quarry, Inc., 1942–1953; Marks Materials, 1953–1967; and Rhodes-Jamieson since 1967. Just when Ideal Cement Company acquired ownership of the property is not known, but the limestone has not been used to manufacture cement.

This deposit has been described and mapped as a 200-foot-thick sequence of limestone and associated chert exposed over a triangular area 1,400 feet by 900 feet (Darrow, 1963, p. 12-13, plate 1). It originally was exposed through more than 300 feet of relief from sea level to the top of the hill. The beds form a syncline that plunges 45° NW, and they are truncated on the north by a fault. Minor faults and folds also seem to complicate the structure locally. The mass consists of

a well-bedded, highly fractured sequence of light and dark limestone with thin interbeds and nodules of chert. The percentage of chert varies from place to place but constitutes a substantial portion of the deposit. Interbeds of greenstone and other altered rocks are also present to some extent. The light limestone is distinct, being light dove-gray, fine grained, dense, and foraminiferal. Limestone that is free from visible impurities is represented by the chemical analysis of sample 2 in table 5. An analysis of a composite sample representing a 35-foot section of light limestone, as given by Walker (1950b, table 2), shows 48.73% CaO and 10.85% SiO₂.

Contrasting with the above is the dark limestone which is generally dark blue-gray, fine crystalline, dense, bituminous, and commonly well laminated and platy. Although not as obviously associated with chert beds as the light limestone, the dark limestone is often quite siliceous. Variations in chemical composition are indicated by samples no. 1 and 3 (table 5), neither of which contained visible chert beds. A composite sample representing a 40-foot sequence of dark limestone is shown by Walker (1950b, table 2) to contain 44.81% CaO and 16.73% SiO₂. Other analyses are given in Logan (1947, p. 308) and Eckel (1933, table 2).

Table 5. Chemical analyses of limestone from the Rockaway deposit, San Mateo County.

Oxide	Rockaway #1 *	Rockaway #2	Rockaway #3
CaO	25.0%	54.50%	53.50%
MgO	0.5	0.51	0.51
SiO ₂	50.0	1.67	1.57
Al ₂ O ₃	0.38	0.19	0.35
Fe ₂ O ₃	0.30	0.10	0.17
P ₂ O ₅	0.08	0.07	0.16
TiO ₂	0.08	ND	ND
Organic C	2.7	ND	ND
Ignition loss (less C)	22.0	42.96	43.39
Total	101.04	100.00	99.65

ND = Not done

* Adjusted analysis.

Sample 1—typical dark blue-gray finely-crystalline, bituminous limestone with no visible impurities.

Sample 2—typical light dove-gray, fine-grained, foraminiferal limestone with no visible impurities.

Sample 3—similar to sample 1 but partly weathered buff and platy.

Analyzed by Lydia Lofgren, California Division of Mines and Geology, 1962

When examined in May 1962, the deposit was developed from the southeast side by a quarry about 500 by 700 feet with a maximum face of about 150 feet. This is bordered to the north and west by a series of benches, the highest of which may be 200 feet above the quarry floor. A tunnel adit on the east side of the deposit is all that remains to indicate the former glory-hole operation of E. B. and A. L. Stone Company. From the extent of the workings in 1962, it is estimated that roughly 3 million tons of materials have been quarried at this deposit.

In recent (1962) quarry operations, the fractured limestone and chert are ripped from the upper benches and bulldozed to the quarry face, falling to the quarry floor below. Only occasional blasting is needed. Some selective quarrying is necessary to maintain a uniform product. Thin soil overburden and occasional soft, noncarbonate interbeds are moved to the west slope of the hill where they are wasted. At the quarry floor, the rock is bulldozed to a grizzly, where the oversize rock is reduced in a jaw crusher. Both fractions are conveyed to the crushing-screening plant, which has a capacity of 250 tons per hour. At the plant, the minus 1½-inch material is removed and stored for use as road base material. The plus 1½-inch rock is crushed to five sizes, including sand, by one jaw and three cone crushers and a roll. The material is then stored in open piles for use as asphalt and portland cement concrete aggregates, drain rock, roofing gravel, and other purposes. Processing is dry, although some products are occasionally washed. Large boulders left in the quarry are used for riprap and landscaping. Most of the aggregate produced is utilized at the quarry in an asphalt plant owned by Marks Material, Inc., and a readymix concrete plant owned by H. E. Casey of San Mateo.

Available reserves of the Rockaway deposit amount to about 2 million tons of usable rock above sea level—assuming the limestone extends to that depth throughout the deposit and the amount of wastage does not increase significantly.

Other references: Lawson, 1914, p. 22 and map; Kelly, 1933, p. 362–363; Walker, 1950b, p. 4, 5, 7.

San Francisco Bay Shell deposits (Ideal Cement, Pioneer Shell, South Bay Dredging, Bay Shell). Location: South arm of San Francisco Bay; mainly T. 3 and 4 S., R. 3 and 4 W., M.D.; San Mateo, Hayward, and Palo Alto 15-minute quadrangles. Ownership: Multiple, but mainly Ideal Cement Company, 420 Ideal Cement Building, Denver, Colorado 80202, and State of California (1967).

Accumulations of shells are found in many of the shallow bays and inlets of California. By far the largest are the accumulations of native oysters (*Ostrea lurida* Carpenter) deposited in Holocene time in south San Francisco Bay. The deposits of south San Francisco Bay have served as the principal sources of shells dredged in California and, since 1962, have been the sole source of shells dredged in the state. Prior to 1962, oyster shells also were dredged commercially from Newport Bay in Orange County.

Although oyster shells were obtained from San Francisco Bay as early as 1891 for garden walks and other purposes (Skinner, 1962, p. 95), shells were first dredged commercially in 1924 for livestock feed and soil conditioning. Since 1925, when a cement plant began production at Redwood City, the shells have served mainly as cement raw materials. From 1931 to

about 1950, shells also were calcined to make lime, which was used for reacting with salt works bittern to produce magnesium compounds. In recent years, three companies have been active in shell dredging. Ideal Cement Company was the major producer, utilizing shells and associated mud for the production of cement. * Pioneer Shell Company dredges and processes shells mainly for cattle and poultry feed. South Bay Dredging Company also dredged and washed shells but sold all of their product to Bay Shell Company for further processing and eventual sale for livestock feed and soil conditioning. **

A summary of past and present operations, as of 1969, is given in table 6. More detailed data appear below under individual company descriptions.

Occurrence of Shells

In spite of many years of commercial shell dredging, numerous technical reports on the sediments of the bay, and thousands of drill, core, and dredge samples collected, surprisingly little detail is known about the size, extent, and characteristics of the individual shell accumulations. Most investigations of the bay sediments treat the shell occurrences incidentally or in only general terms. The sediments of San Francisco Bay are probably best summarized by Treasher (1963) and Trask and Rolston (1951). Detailed data on the Holocene sediments, in which most of the shells occur, are presented in unpublished reports by Conomos (1963) and Gram (1966). Investigations specifically concerned with shell deposits are reported by Hart (1966a) and Story *et al.* (1966). Many other pertinent references are listed by Trask (1953), Terry (1955), and Goldman (1969).

The principal shell accumulations consist of native oysters deposited in the shallow parts of south San Francisco Bay. Most of the deposits lie in the upper part of a Holocene soft mud unit—referred to as “younger bay mud” by Treasher (1963). Partly veneering this unit are surficial modern oyster shell accumulations. Both the mud-associated and the surficial deposits have been dredged commercially, but the former constitute by far the largest reserves. Shells exposed on the bay bottom, excluding peripheral beaches and bars, indicate the general areas where buried shell deposits exist (figure 2).

Smaller deposits of oyster shells also occur with older bay mud but are too small and deeply buried to be of economic value. Fragmental shells (mostly clams) associated with sand in several parts of the bay conceivably could be a source of shells but have not been dredged for that purpose.

The principal shell occurrences—younger bay mud deposits, surficial deposits, and shells associated with sand—are described below.

* Shell-dredging and cement manufacture by Ideal Cement Company ceased at the end of 1970. (See footnote below under Ideal Cement Company).

** Shell-dredging by South Bay and processing by Bay Shell ceased in 1969.

Figure 2. Map showing distribution of oyster shells in southern San Francisco Bay.

Table 6. Summary of known producers and processors of oyster shells of south San Francisco Bay.

<i>Name of operator and years active</i>	<i>Source of shells</i>	<i>Remarks</i>
Bay Shell Co. (was Agricultural Lime & Compost Co.) 1924-1969	Purchased from South Bay Dredging; previously purchased from Beck Dredging; also may have dredged near Alviso and San Mateo Bridge pre-1950(?).	Processed shells for livestock feed and soil conditioning at plant in Alviso. Operations ceased 1969
Ideal Cement Co. (was Pacific Portland Cement Co.) 1925-1969 (active)	Dredges shells and mud east of channel near San Mateo Bridge and harges to plant; also buys washed shells from Beck Dredging.	Manufactures cement at Redwood City plant, using washed shells to "sweeten"; previous to 1950 washed and processed shells for livestock feed and soil conditioning.
Ortley Shell Co. (W. B. Ortley) 1930-1941	Reportedly did own dredging.	Shells processed for poultry feed at Alviso plant.
Pioneer Shell Co. (Capt. L. H. Beck, Beck Dredging Co.) 1931-1969 (active)	Dredges near San Mateo Bridge east of channel; may have dredged south of Dumbarton Bridge.	Washes shells on dredge and delivers to own plant in Petaluma for livestock feed and soil conditioning; previously sold washed shells to Ideal Cement, Westvaco Chlorine Products and Bay Shell companies; formerly processed shells for commercial sale at plant near Alviso.
South Bay Dredging Co. (Pete Gambetta) 1953 (or earlier)-1969	Dredged north of San Mateo Bridge and east of channel; probably dredged south of Dumbarton Bridge earlier.	Washed shells on barge and sold to Bay Shell Co. Operations ceased 1969
Westvaco Chlorine Products Corp. (was California Chemical Corp.; now is Inorganic Chemicals Div., FMC Corp.) 1931-1948	Purchased from Beck Dredging.	Shells calcined and reacted with bittern to make magnesian compounds at Newark plant; some lime, hydrated lime, and poultry feed sold commercially (see FMC Corp.).

Younger bay mud deposits. This unit is widely distributed in San Francisco Bay. It consists mainly of soft gray mud (silty clay) with interbeds and lenses of silt, sand, peat, and shells. These sediments were deposited following a progressive rise in sea level after the last glacial episode (Wisconsin Glaciation). Shells accumulated in an environment similar to the present one. The shells exist as numerous thin lenses of variable purity that are interbedded with and grade laterally into mud. The lenses are largely concentrated in the upper 30 or 40 feet of the younger bay mud unit. Test borings show that shell-mud sequences as much as 25 feet thick exist in several places in south San Francisco Bay and also at the west end of the Richmond-San Rafael Bridge at the north end of the bay.

Thick sequences of shells probably represent relatively persistent environments favorable to the growth and accumulation of shells. Shell lenses also tend to concentrate along certain horizons that are laterally extensive. Such horizons reflect periods of greatly increased populations (population explosions) of the native oyster. The most extensive shell horizons known lie east of the main ship channel in south San Francisco Bay.

In 1962, Ideal Cement Company explored these deposits with 107 drill and core holes in order to evaluate their shell holdings. According to Story *et al.* (1966, p. 48), the shell horizon in the vicinity of the San Mateo Bridge is "a fairly extensive layer containing 4 to 15 feet of oyster shells buried beneath 2 to 8 feet of mud". The layer is reported to contain 10 to 75% shells (dry basis). Radiocarbon age dates indicate

that this shell horizon was deposited 2300 to 2500 years ago (Story *et al.*, 1966, p. 48-49). Because most of the dredged shells are worn and somewhat broken, it is presumed that the shell deposits are at least partly reworked debris from oyster reefs and beds or from older deposits. However, it is likely that eroded remnants of ancient reefs are partly preserved.

Shell deposits of the younger bay mud contain the bulk of the commercial shell reserves and provide the raw materials for cement manufacture by Ideal Cement Company.

Surficial shell deposits. Although the native oyster population has been somewhat decimated since 1900 due to pollution (Skinner, 1962, p. 100), live oysters can be found in many places in sheltered parts of San Francisco Bay (J. A. Aplin, 1968, personal communication). Extensive beds and cemented reefs, with clusters of live oysters attached, are most extensive in shallow parts of the south arm of the bay. Oysters are also reported in a few places along the rocky perimeter of the bay. Debris derived from oyster environs, and perhaps from older deposits, too, has accumulated as veneers and bars. These loose-shell deposits, as a result of wave and current action, tend to migrate shoreward to form beaches in San Mateo County. Such beaches are reported to have been rather extensive around the turn of the century. The submerged bars, veneers, and loose debris around the reefs are easy to dredge hydraulically and are believed to be the principal sources of shells used by Pioneer Shell Company and South Bay Dredging Company. The beaches, although composed almost entirely of clean shells, are not known to

Photo 1. Western margin of San Francisco Bay showing shell barrier beach (foreground) and spits which form small tidal lagoon on east side of Brewer Island, San Mateo County. Beach and spit formed after construction of levees around man-made island.

Photo 2. Close-up of shells (mostly native oysters) that comprise spit of Brewer Island, San Mateo County, formed by wave action in San Francisco Bay.

be used commercially, although they may have been in the past.

Shells associated with sand. Fragmental shells, perhaps composed mostly of clams, are associated with sand in shoal areas north of San Francisco where currents are strong. Sand-shell deposits are shown to be exposed northwest and southwest of Angel Island by Trask (1953, figure B-3). Samples of dredgings just west of Alcatraz Island are reported to contain at least 50% shells. A 15-foot-thick layer of sand containing an undetermined percentage of broken shells also is known at San Bruno Shoal, where the sand is buried under 15 to 20 feet of mud and shells. This shelly sand has been used extensively for hydraulic fill at Foster City. Whether the shells are distributed through the sands or are locally concentrated is unknown. In either case, it is conceivable that the shell debris, which tends to be coarser than the associated sand, could be easily beneficiated by screening. Shell-bearing sand deposits of San Francisco Bay have been dredged solely for fill purposes so far.

Composition of Shell Deposits

Samples indicate that more than 95% of the shells dredged commercially are derived from the very prolific and widespread native oyster *Ostrea lurida* Carpenter. This oyster produces a rather flat and very thin shell that is a maximum of 2½ inches long. Minor amounts of debris from other mollusks, plus barnacles and bryozoa, also are present. The presence of the Japanese littleneck clam, introduced into the bay in 1930, readily differentiates the modern shells from those dredged from older buried deposits. Imported oysters, once raised commercially, may also constitute some of the surficial shell debris locally.

As indicated above, the most important shell deposits or horizons consist of multiple shell lenses in mud. The discrete shell lenses also contain variable amounts of interstitial mud. Specific data on the compositional

variations of individual shell lenses and groups of lenses are not available. However, some idea of the chemical composition of a high-grade mud-associated shell deposit is indicated by sample 1 in table 7. The sample is a product of hydraulic dredging and undoubtedly is higher in lime (CaO) than the in-place sample because of the inherent washing effect of the dredging process. Sample 2 (table 7), which is the same as sample 1 except that it has been washed, contains 53.8% lime. Samples 3 to 7 are washed shells from surficial deposits and contain 53.07% to 54.31% lime. Unwashed sample 8 from a shell beach contains 52.9% lime.

Development and Reserves

It is estimated that 25 to 30 million tons of shell have been dredged from south San Francisco Bay since 1924. The great bulk of this was used in the manufacture of cement. Most of the shells dredged came from the vicinity of the San Mateo Bridge east of the main ship channel (see figure 2). Some dredging has been reported south of Dumbarton Bridge, and bottom depth changes recorded in nautical charts of different years indicate that additional dredging has been done near the Oakland Airport, south of Alameda. Recent dredging by Ideal Cement Company has been conducted just north of the San Mateo Bridge causeway. The company operates* a hydraulic dredge with a cutter head to develop a bench-cut that is worked eastward. Pioneer Shell Company and South Bay Dredging Company** dredge hydraulically in water no deeper than 10 or 11 feet, reportedly near the San Mateo Bridge causeway. Surficial deposits of loose shells that veneer the bay bottom or accumulate locally are believed to be the main sources of shells used by these companies. Both Pioneer and South Bay wash the shells aboard their dredges prior to later process-

* Operations ceased at end of 1970.

** South Bay ceased dredging in 1969.

Table 7. Chemical analyses of oyster shell samples from south San Francisco Bay.

<i>Oxides (dry weight basis) in percent</i>	1	2	3	4	5	6	7	8
Ignition loss	36.94%	43.47%	43.14%	43.86%	43.60%	43.00%	43.60%	43.60%
CaO	45.14	53.80	53.07	54.31	53.2	53.1	53.1	52.9
MgO	1.58	0.34	0.51	0.51	0.44	0.74	0.64	0.62
SiO ₂	9.70	1.40	2.15	0.98	0.72	1.5	0.74	0.83
Al ₂ O ₃	1.84	0.15	0.34	0.11	0.43	0.84	0.37	0.47
Fe ₂ O ₃	1.65	0.11	0.24	0.09	0.11	0.16	0.09	0.09
P ₂ O ₅	0.17	0.05	0.05	0.05	0.04	0.05	0.05	0.06
N ₂ O	1.86	ND	ND	ND	ND	ND	ND	ND
K ₂ O	0.43	ND	ND	ND	ND	ND	ND	ND
Total	99.31%	99.32%	99.50%	99.91%	98.54%	99.39%	98.59%	98.57%

ND=Not done

Samples 1-4—analyzed by L. Lofgren, 1962

Samples 5-8—analyzed by C. Smith and M. Tavela, 1967

Sample 1—from Ideal Cement Co. barge, Redwood City plant, unwashed sample dredged east of channel near San Mateo Bridge

Sample 2—same as sample 1 but washed by hand over a 28-mesh screen

Sample 3—from primary stockpile of Pioneer Shell Co., Petaluma; sample dredged, washed and screened near San Mateo Bridge

Samples 4 and 5—from primary stockpile at Bay Shell Co., Alviso, shells dredged, washed and screened near San Mateo Bridge by South Bay Dredging Co.

Samples 6 and 7—dried, crushed and screened shell from Bay Shell Co. plant, Alviso. Sample 6 is "medium shell"; sample 7 is "flour shell"

Sample 8—unwashed shell from beach at Brewer Island, San Mateo County

ing for livestock feed and soil conditioning. (See company descriptions below for additional data.)

Reserves of oyster shells are difficult to ascertain with the data available. However, it is believed that at least several tens of millions of tons of shells are available at a shallow depth (within 20 to 30 feet below the bay bottom) east of the main ship channel in south San Francisco Bay. Smaller reserves also veneer the bay bottom in the same area. Shell deposits along the San Mateo County shore and elsewhere in the bay are probably small but may be of economic value. Some of the deposits south of the Dumbarton Bridge and along the San Mateo shore reportedly have been used in the past.

Economics

The shell deposits of San Francisco Bay are actually thin, low-grade, unconsolidated limestone deposits that would be far less valuable (or even useless) if located onshore. Some of the advantages enjoyed by the shell operators include: 1) simple and inexpensive mining by dredging; 2) ability to beneficiate the shells inexpensively by washing with bay water; 3) use of the mud impurities as a source of raw materials (alumina, silica, iron oxide) in the manufacture of cement; 4) flexibility and low cost of transportation of products within a large marketing area; and 5) low land cost, especially for an urbanized region.

The disadvantages associated with shell development are not always obvious but generally relate to multiple use and multiple jurisdiction of the Bay. Manifold problems can develop when dredging, land filling, shipping, sport and commercial fishing, and various recreational activities are all carried on in close proximity to one another. The varied activities and different areas of the bay are managed by several local government agencies, as well as by numerous private land owners.

Land ownership in south San Francisco Bay is complex, and mineral rights to large areas are owned by both public and private entities. The State of California owns most of the public land, but some land is held by cities and other government jurisdictions. The largest private owner, Ideal Cement Company, reportedly controls about 30,000 acres of bay land between Millbrae and Alviso. The approximate distribution of lands owned by Ideal is indicated by Scott (1963, chart opposite p. 4) as lands patented by the Surveyor General. An additional 4,730 acres of State-owned land is leased by Ideal Cement Company for the purpose of shell dredging.

Shell Producers and Processors

*Bay Shell Company*¹. This company operates a shell-processing plant at 3780 Lafayette Street, Alviso, Santa Clara County. Bay Shell Company has processed oyster shells dredged from San Francisco Bay

since 1924. During its early years, the company reportedly dredged shells from "near Alviso" (Logan, 1947, p. 311) and "a point about 2½ miles north of the San Mateo drawbridge" (Davis and Jennings, 1954, p. 391). In recent years, all of the shells processed by the company were purchased from South Bay Dredging Company (which see). Some shells also were purchased from Beck Dredging Company (now Pioneer Dredging Company) at least as early as 1946. Records indicate that Bay Shell Company may have dredged shells as late as 1956. The company was owned by Santa Clara Sand and Gravel Company in 1962 and by Steve Dorsa of Saratoga in 1967.

When visited in 1962 and 1967, Bay Shell Company received washed shells by barge at its plant on Alviso Slough. Approximately four barge loads (capacity 1,000 cubic yards) per month were being delivered. The shells are unloaded with a clamshell and conveyed to a small gas-fired rotary kiln for drying. The dried shells are sized over a multiple hummer screen having openings of ½ inch to 10 mesh. A hammer mill is used to produce finer sizes. Four sizes—whole shell, medium, fine, and flour—are produced. These are sacked separately or combined as desired. Most of the shell is sold as poultry feed, but "flour" is sold for soil conditioning and livestock. Based on the name of its predecessor company—Agricultural Lime and Compost Company—the products were marketed as ALCO Products until recently. The products are now marketed under the Bay Shell name. Chemical analyses by Abbot A. Hanks, Inc., of two finished product samples collected in 1967 showed an average content of 53.1% CaO (see samples 6 and 7, table 7). Samples of washed, but otherwise unprocessed, shells taken from the primary stockpile in 1962 and 1967 averaged 53.7% CaO (see samples 4 and 5, table 7). Capacity of the plant was 7 tons per hour, but this was expanded in late June 1962. Although the property is served by a spur of the Southern Pacific Railroad, all products were being trucked to market in 1967.

Photo 3. Bay Shell Company processing plant at Alviso showing hopper for dredged and washed shells, conveyor belt, rotary drier, screening tower, and storage silos. Plant ceased operations in 1969.

¹ The Bay Shell Company plant ceased operations in 1969.

FMC Corporation (Food Machinery and Chemicals Corporation; Westvaco Chlorine Products Company; California Chemical Corporation). Westvaco Chemical Division (now known as Inorganic Chemicals Division) of FMC Corporation and its predecessors purchased oyster shells to manufacture lime at their Newark plant from 1931 to about 1948. Most of the lime was used to react with seawater bittern to precipitate magnesium hydroxide—a basic raw material used extensively in the chemical and basic refractories industries. Some lime and hydrated lime made from shell also were sold commercially—perhaps as late as 1950. In addition, small amounts of shell were sold as poultry feed.

The shells were purchased from Captain L. H. Beck, who dredged in the southern arm of San Francisco Bay (see Pioneer Shell Company). Although Westvaco formerly owned shell-bearing land, the deposit was never developed. The land eventually was acquired by the Airport Authority for extension of runways of San Francisco Airport. Recovery of shells by Captain Beck was by suction dredging. The shells were washed free of mud aboard Captain Beck's dredge and transferred by barges, via Newark Slough, to the plant at Newark. Here, the shells were burned in a gas-fired rotary kiln 315 feet long by 7½ feet in diameter. In order to obtain a quality quicklime, the kiln had a basic refractory lining and was operated at temperatures as high as 1,600°C (Seaton, 1931, p. 641; 1942, p. 23). Capacity of the lime plant was about 12,000 tons per year. The lime product was reported to contain less than 0.5% SiO₂, around 0.2% Fe₂O₃, 0.2% Al₂O₃, and about 1.0% MgO. A detailed discussion of the reaction of quicklime with bittern and other processing data are given by Seaton (1942).

From 1947 to 1968, magnesian lime made from calcined dolomite was used instead of high-calcium lime to take advantage of the magnesium available in dolomite. The dolomite was obtained from the company's Westvaco deposit in San Benito County (see Westvaco deposit under Gabilan Range District) and calcined at the Newark plant until operations ceased in August 1968.

Other references: Lagan, 1947, p. 205; Davis, 1950, p. 298–300; Ver-Planck, 1957, p. 319, 322; Bowen and Gray, 1959, p. 37; Goldman, 1967, p. 24–25.

Ideal Cement Company (Pacific Portland Cement Company). Ideal Cement Company (420 Ideal Cement Building, Denver, Colorado 80202) owns and leases about 35,000 acres of tide and submerged land in south San Francisco Bay. Large shell deposits within this area provide the principal raw materials used at the company's cement plant located at the Port of Redwood City.*

Pacific Portland Cement Company constructed a portland cement plant at Redwood City in 1924—apparently to supplant the production from its Cement Hill plant in Solano County, which was largely importing limestone. It was planned to utilize oyster shells and associated mud of San Francisco Bay as a basic resource at the new plant. Control of the principal shell deposits of San Francisco Bay was attained when the cement company acquired the holdings of the Morgan Oyster Company. The latter company not only owned a large acreage of oyster beds on both sides of the Bay between Millbrae and Alviso, but also leased 4,730 acres from the State of California in 1923 for the purpose of dredging shells. This lease also was taken over by Pacific Portland Cement Company. In 1958, the lease expired and a new renewable lease (Public Resources Code 1850.1) was issued to Ideal Cement Company (successor to Pacific Portland Cement Company in 1952) for the same area. The lease area is situated just north of the San Mateo Bridge causeway in T. 3 S., R. 3 W., T. 4 S., R. 3 W., and T. 4 S., R. 4 W., M.D. The oyster shell deposits so acquired have been the sole source of lime since 1925, when production began, and the mud associated with the shells has provided the principal source of silica, alumina, and iron oxide.

Since the expansion of the plant in 1927, when cement production capacity was raised to 5,000 barrels per day, there has been no extensive expansion of the Redwood City plant. However, certain plant changes between 1927 and 1966 have increased production capacity about 40%. By assuming that production has been close to capacity and that shells are the sole source of lime in cement manufacture, it is estimated that approximately 25 million tons of shell (excluding mud) have been produced since 1925. Practically all of this was used to manufacture cement, although small amounts of shells were washed and processed consistently from 1927 to 1950 for use in soil conditioning and livestock feed. The latter products were marketed under the "Empire Brand" name. It is further estimated that at least 6 to 7 million tons of mud was produced with the shells during 1925–1967. Most of the mud produced was used in the manufacture of cement.

Land controlled by Ideal Cement includes most of the shell deposits of southern San Francisco Bay, shown in figure 2 and described above. All of Ideal's recent production and perhaps most of the past production has come from a 4- to 15-foot thick shell layer in the vicinity of the San Mateo Bridge causeway (Story et al., 1966, p. 48). Shells and associated soft bay mud (silty clay) are obtained by one of two dredges (one is kept on standby), each of which is fitted with a 15- or 16-inch suction pipe and cutter head (Davis,

* Ideal Cement Company ceased shell dredging operations and cement manufacture at its Redwood City plant at the end of 1970. On November 20, 1970, the company announced plans to close the plant because of the high capital cost of bringing the old and inefficient plant up to air pollution control standards set by the State of California. (Plans to close the com-

pany's San Juan Bautista plant, announced concurrently, were later rescinded.) It was planned to continue to use the facility as a distribution terminal for cement manufactured at Ideal's new cement plant in Seattle, Washington.

1955, p. 416). Shells were dredged north of the San Mateo Bridge causeway during the 1960s (see figure 2). Dredging is conducted by making successive "passes" along the cut face of a shallow bench. A bench is thus formed and worked shoreward to the east. Steel barges are loaded with about 700 tons of unwashed shells and mud and towed to the Redwood City plant by tugs. A clamshell bucket and overhead crane unload the shells and stockpile them on the dock adjoining the plant. Analyses of the unwashed and washed shells are given in table 7. Excessive mud is removed from the shells by washing in a screw classifier, if necessary, but most of the mud is used in cement manufacture. The slurry also can be "sweetened" by adding washed shells. Washed shells are obtained from Pioneer Shell Company.

Photo 4. One of two shell dredges operated by Ideal Cement Company. Dredge made successive passes along face of shallow bench cut in shells and mud. Dredged shells and mud were screened and conveyed to adjacent barge (700-ton capacity) and towed to cement plant at Redwood City. Dredging and cement manufacture ceased at the end of 1970. Photo by Edward E. Welday, 1970.

The shells and mud are ground and blended with iron scale or iron ores and other ingredients to make a slurry of proper proportions. This is dewatered and fed to four gas-fired rotary kilns which operate at temperatures up to 2,800°F. Clinkers, which are less than an inch in size, are cooled to 250°F. The clinkers are ground with purchased gypsum and stored in silos for marketing (Bowen and Gray, 1962, no. 8, p. 2). In addition to iron scale, the company purchases large amounts of hydrochloric acid, possibly to reduce the alkalies in the final product. Shale of the Monterey Formation, obtained from the company's quarry at Chittenden, Santa Clara County, has been used in the raw feed since 1965 and at times prior to that. Only Type I cement is produced due to the high alkali content of the bay mud used.

About 200 people are employed at the plant, which has a rated capacity of 2,510,000 barrels of cement per year. About 90% of the cement is shipped bulk; the remainder is bagged. Deep-water port facilities enable the company to ship cement to markets in Oregon and

Washington, although the great bulk of the cement is transported by truck to local markets.

Other references: Senior, 1929, p. 247-251; Logan, 1947, p. 307-308.

W.B. Ortle Shell Company. This company dredged and processed small amounts of shells from San Francisco Bay from 1930 to 1941. Dredging was done using a rotary pump mounted on a barge. The shells were barged to a plant near Alviso for drying, crushing, and screening prior to sale as poultry feed (Franke, 1930, p. 9; Logan, 1947, p. 312). Location and nature of the shell deposits worked are undetermined.

Pioneer Shell Company (L.H. Beck; Beck Dredging Company). The company is owned by Captain L.H. Beck, 2772 Bromely Road, San Carlos. Captain Beck dredged shells from south San Francisco Bay from 1931 to 1947 (or later) under the names L.H. Beck and Beck Dredging Company, and from 1956 (or earlier) to the present time (1967) under the name Pioneer Shell Company. Locations of earlier dredge grounds are unknown, but dredging in recent years reportedly has been conducted east of the ship channel in the vicinity of the San Mateo Bridge, both north and south of the bridge causeway. Some of the shells were processed for livestock feed and soil conditioning, first at a plant in Alviso and later at the present plant at 100 "D" Street in Petaluma. Large amounts of washed shells also were supplied to Ideal Cement Company, FMC Corporation, Bay Shell Company, and possibly others.

In June 1962, Pioneer Shell Company obtained shells from the shallow water area north of the San Mateo Bridge causeway near the boundary of Alameda and San Mateo Counties (figure 2). The exact nature of the deposit is not certain but probably consists largely of surficial accumulations of loose shells associated with soft bay mud. Dredging is conducted with a suction dredge, 1,500-cubic-yard and 800-cubic-yard barges, and two tugboats. The tugboats are used both for dredging and barge transfer. The dredged shells and associated mud are pumped from the bay floor to a trommel where bay water is used to free the shells of mud. The mud and shell fines are wasted overboard and the cleaned shell is conveyed to an adjacent barge. When loaded, the barge is towed to the company's plant at Petaluma for further processing. The washed shells consist almost entirely of native oyster shells (*Ostrea lurida* Carpenter). Other mollusks (Japanesc littleneck clam, bent-nose clam, bay mussel, and an unidentified ornate gastropod), including some live ones, constitute 5% or less of the shells. A chemical analysis of the washed shells shows 53.07% CaO (sample 3, table 7).

At the Petaluma plant there are dock facilities where the shells are unloaded from the barge by means of a clamshell and stored. The shells are then dried in a gas-fired rotary drier and sent to a set of screens for sizing. Some whole- and half-shell sizes are

separated and stored for sale, but most of the material is reduced in size by rolls or in a hammer mill to obtain "fine" and "flour" products. The four sizes (whole shell, half shell, fine, and flour) are sold separately or combined as needed—mainly for poultry and cattle feed. Some shell also is sold for chemical uses and soil conditioning. The products are sacked and shipped as far as Seattle. The shell products are marketed as "Conestoga Brand Products" and guaranteed to contain at least 94% calcium carbonate. Capacity of the Petaluma plant is not known, but it is reported that approximately one barge-load (1,500 cubic yards) of shells is processed each week.

In addition to the shells processed in Petaluma, large amounts of washed shells are barged to the Ideal Cement Company plant in Redwood City to "sweeten" the raw material used to manufacture cement.

References: Logan, 1947, p. 311; Davis and Jennings, 1954, p. 407.

*South Bay Dredging Company.** This company is owned by P.J. Gambetta (Route 1, Box 78, Brentwood), who has dredged shells from San Francisco Bay since 1953 or earlier. He reportedly dredged south of the Dumbarton Bridge prior to 1960 but, since then, apparently has relocated to an unspecified area north of the San Mateo Bridge causeway. Most of the production since 1953 has been sold to Bay Shell Company (which see) for further processing and marketing. There is no record of production prior to 1953, although there is some indication that Gambetta may have dredged shells at least as early as 1945 and may have sold shells commercially.

South Bay Dredging Company uses a self-propelled suction dredge capable of operating in water as deep as 10 or 11 feet. Dredging is done through two suction pipes trailing aft while the dredge pushes a 1,000-cubic-yard barge. Shells and associated mud are pumped as a slurry into two separate trommels measuring about 4 feet by 20 feet. Washing is effected by salt bay water sprayed from an axial pipe running the length of the trommel. Mud and fine shells are washed through the $\frac{1}{8}$ - or $\frac{1}{2}$ -inch mesh trommel screen and washed aft. The coarse shells are pumped as a salt water slurry to the barge where water and some additional clay and silt are allowed to drain from the shells through screened openings. When loaded, the barge is delivered via Alviso Slough to Alviso, where Bay Shell Company purchases the entire production.

The shells dredged probably occur as thin surficial deposits associated with soft mud and distributed over a large irregular area along the east side of the Bay (see description above and figure 2). A chemical analysis of the washed shells dredged by South Bay Dredging Company shows 54.31% and 53.2% CaO (samples 4 and 5, table 7). The shells are somewhat broken and slightly abraded, being a maximum of about 2 inches

long. They are derived almost entirely from the native oyster; but a small percentage consists of the Japanese littleneck clam, bent-nose clam, bay mussel, and other mollusks, some of which are dredged live.

Photo 5. Self-propelled dredge and barge of South Bay Dredging Company. Shells and mud were pumped from bay floor through two pipes aft (in raised position) and washed through two trommels before being pumped through pipe (fore) into 1,000-cubic-yard capacity barge (left). Company ceased operations in 1969.

San Mateo Creek deposits. Location: Sec. 18, T. 4 S., R. 5 W., M.D., 3 miles southeast of Rockaway Beach (Pacifica); San Mateo 15-minute quadrangle. Ownership: City and County of San Francisco Water Department (1962).

Four discontinuous masses of Franciscan limestone, extending 3,500 feet northwestward across the divide between San Pedro and San Mateo Creeks, are shown by Darrow (1963, plate 1). The largest mass has maximum dimensions of 1,000 feet by 350 feet and consists largely of light-gray, dense limestone interbedded with chert. The indicated size of this body is questioned because only scattered outcrops were observed during a cursory examination in May 1962. However, vegetation tends to obscure the extent of the deposit and a positive evaluation was not possible. According to Darrow, there are several smaller limestone lenses in sec. 20 a mile to the southeast. No quarries or other improvements were seen, although Irean (1888, p. 534) states that limestone occurs "at the headwaters of San Mateo Creek, where lime was formerly burned."

Skyline (Tyson) deposit. Location: S $\frac{1}{4}$ cor. sec. 12 (proj.), T. 5 S., R. 5 W., M.D., 5 miles west of Belmont; San Mateo 15-minute quadrangle. Ownership: City and County of San Francisco Water Department (1964).

The Skyline deposit lies just west of Skyline Boulevard and half a mile southwest of the spillway of Crystal Springs Reservoir. It is not certain when this deposit was first opened, but W. O. Tyson (Logan, 1947, p. 309) was one of the early operators in 1945 and 1946. Although the operator in 1948 is not identified, Walker (1950b, p. 7) reports that production at the Skyline quarry was about 1,500 tons per day. From

* The company reported it ceased its shell-dredging activities as of May 31, 1969.

about 1952 to early 1962, the operator was Skyline Materials, Inc. (Howard E. Marks), of Belmont. That company produced large amounts of crushed rock until their lease expired. Reportedly, the City of San Francisco considered the quarry operation a threat to the quality of water stored for domestic use in Crystal Springs Reservoir.

The deposit consists of limestone and related rocks of the Franciscan Formation. It is exposed over a northwest-trending area at least 1,500 feet long by a maximum of 350 feet wide. Additional exposures of limestone 1,500 and 3,000 feet to the northwest in sec. 12 may be a continuation of the deposit, but intervening vegetation and soil cover prevent a definite correlation. Weathered volcanic rock of the Franciscan Formation flanks the deposit on both sides (Lawson, 1914, map; Davis, 1955, p. 437). Faulting has severely crushed and disrupted the deposit, causing the rock to be highly fractured and obscuring the structure.

The limestone is typically of two basic types: 1) light gray, fine grained, and foraminiferal; and 2) dark blue gray, fine crystalline, and bituminous. Chert is commonly interbedded but appears to be less prevalent than usual for Franciscan limestone deposits. One representative sample of material collected from the $\frac{1}{2}$ -to 1-inch stockpile in 1962 contained 15 to 20% chert. Greenstone and possibly other rock types are present in small amounts as interbeds or in-faulted material. The only available chemical analysis, from a "70-foot part of the stratigraphic section", is given by Walker (1950b, table 2) as 43.76% CaO, 0.29% MgO, 1.95% Al_2O_3 , 0.33% Fe_2O_3 , and 18.74% SiO_2 . Development consists of a quarry perhaps 1,200 to 1,500 feet long and 200 to 400 feet wide with a maximum face of 100 feet on the southwest and 30 feet on the northeast. Operation of the quarry is described by Davis (1955, p. 437-438). The last operator, Skyline Materials, Inc., produced crushed and screened rock mainly for road base materials, bituminous and concrete aggregates, and drain rock. In May 1962, the crushing-screening plant was idle. Total production for the Skyline deposit is probably close to 3 million tons. The extent of the limestone reserves cannot be determined until the depth and the continuity of the deposit to the northwest are explored.

Spring Valley Ridge deposits. Location: SE $\frac{1}{4}$ sec. 19 and E $\frac{1}{2}$ sec. 29, T. 4 S., R. 5 W., M.D., 4 miles southwest of Millbrae; San Mateo 15-minute quadrangle. Ownership: City and County of San Francisco Water Department (1962).

Darrow (1963, plate 1) shows several small- to medium-sized lenses of Franciscan limestone along Spring Valley Ridge. Most of the deposits lie at the southeast end of the ridge near Pilarcitos Lake (Reservoir), mainly in E $\frac{1}{2}$ sec. 29. The largest deposit here is shown by Darrow to be a maximum of 1,200 feet long by 400 feet wide. It consists of highly fractured light- and dark-gray limestone with notable amounts

of interbedded chert. It is exposed through at least 150 feet of relief at the top of the ridge and contains reserves of close to 30,000 tons of limestone and chert per foot of depth. Several small limestone deposits nearby have not been examined. Another deposit, centering in SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 19 about a mile to the northwest, is situated just southwest of the ridge crest. Darrow shows the deposit to be a lens half a mile long by a maximum width of 300 feet. Only scattered limestone debris was observed in the north part of the indicated lens, and the deposit was not evaluated further.

The only development is a quarry with estimated dimensions of 120 feet by 40 feet and a maximum depth of 10 feet in the large lens in sec. 19. Approximately 2,000 tons of rock have been excavated recently, apparently by the San Francisco Water Department as a local source of road material.

Westvaco Chemical Division, Food Machinery and Chemical Corporation (Westvaco Chlorine Products Company; California Chemical Corporation). This company, now known as Inorganic Chemicals Division, FMC Corporation, formerly (1931 to about 1950) purchased shells from Beck Dredging Company (see Pioneer Shell Company) and manufactured lime at Newark for chemical use and commercial sales (see San Francisco Bay Shell deposits, FMC Corporation). The company quarried dolomite for use in the production of magnesium compounds at its Newark plant, until that plant ceased operations in August 1968 (see Westvaco deposit under Gabilan Range district).

Wiedemann deposit. Location: SE $\frac{1}{4}$ sec. 20 and SW $\frac{1}{4}$ sec. 21, T. 2 S., R. 1 W., M.D., $2\frac{1}{2}$ miles south of San Ramon; Livermore 15-minute quadrangle. Ownership: Fred Wiedemann, Norris Canyon Road, San Ramon (1962).

A 30- to 70-foot-thick lens of light-brown limestone extending west-northwest over a length of a third of a mile is reported on the northeast flank of Wiedemann Hill (Hall, 1958, p. 22, map). The west end of this lens was examined in November 1962 and found to consist of heavy beds of sandy coquina and fossiliferous sandstone. The beds are steeply dipping, up to 10 or 15 feet thick, and are interbedded with sandstone of the Briones Formation (Miocene). The carbonate rocks appear to be too impure to be of economic value.

Unnamed deposit (near Sunol). Location: Sec. 22, T. 4 S., R. 1 E., M.D., $2\frac{1}{2}$ miles southeast of Sunol; Livermore 15-minute quadrangle. Ownership: Not determined.

A large Pliocene "caliche" deposit is shown and described by Hall (1958, map, figure 2) as a mappable unit a mile long by a third of a mile wide and as much as 200(?) feet thick. A smaller deposit also is shown to the southeast. The "caliche" is described as white, commonly containing yellowish-gray siliceous inclusions.

SANTA CLARA DISTRICT (B-4)

This district covers the limestone deposits in Santa Clara County and in southernmost San Mateo County. Roughly 40 million tons of limestone have been produced in the district since 1864, when Guadalupe Lime Company commenced operations. However, only small amounts were produced prior to 1939—mainly for lime and for beet-sugar refining. Since 1939, all of the limestone produced in the district has come from the Permanente deposit. Most of this was used in manufacturing cement; but a substantial quantity of the more siliceous stone has been sold as crushed rock and some high-quality limestone has been sold for beet-sugar refining.

Nearly all of the limestone deposits in the Santa Clara district are part of the Franciscan Formation and are Cretaceous in age. These deposits are situated on the northeast flank of the Santa Cruz Mountains. The Franciscan limestone occurs as numerous discontinuous lenses and masses that form three distinct and separate belts lying west of San Jose, southeast of Los Gatos, and south of Gilroy. Distribution of these limestone bodies is shown by Allen (1946, plate 1), Walker (1950b, plate 1), Bailey and Everhart (1964, plate 1), and Dibblee (1966b). Because numerous chert interbeds occur with the limestone, few deposits have been worked commercially. However, by selective quarrying and hand sorting, some high-grade limestone has been obtained at the Permanente, Los Gatos Lime Company, Guadalupe Creek, and other deposits for use in sugar refining and lime manufacture. With the exception of the Permanente deposit, none of the Franciscan limestone deposits appears to be sufficiently large or pure for industrial use. Many, however, may be useful as local sources of crushed rock.

Cummings *et al.* (1962, p. 192) describe lenses of limestone up to 1,000 feet long and 100 feet thick in the Mindego Formation (Oligo-Miocene) in southern San Mateo County, but there has been no commercial production from any of them.

Brecciated Eocene limestone, associated with Quaternary caliche or calcareous tufa, also was used in limited amounts (see Bernal deposit); but such occurrences no longer appear to be of economic interest. Also, some Holocene shells may have been dredged from the southern tip of San Francisco Bay (see San Francisco Bay Shell deposits under San Francisco Bay district).

The only active limestone quarry in the Santa Clara district is at the Permanente deposit, operated by Kaiser Cement and Gypsum Corporation. This and other deposits and operations are described alphabetically below.

Baldy Ryan deposits. Location: Sec. 13 (proj.), T. 9 S., R. 1 E. and sec. 18, T. 9 S., R. 2 E., M. D., $5\frac{1}{2}$ to 6 miles southwest of Coyote; Los Gatos 15-minute quadrangle. Ownership: Not determined.

Several small to moderate-sized bodies of limestone of the Franciscan Formation form a group extending $1\frac{1}{2}$ miles westward from Baldy Ryan (Longwall) Canyon to Fern Peak (Bailey and Everhart, 1964, plate 1). The largest and most accessible deposits lie at the extremities of the group. The large deposit to the west at Fern Peak is 1,000 feet long by a maximum of 75 to 100 feet wide. To the east in Baldy Ryan Canyon is a similarly narrow deposit 1,700 feet long. This deposit contains an unusual oölitic limestone that is exposed conspicuously. Bailey and Everhart (1964, p. 23) describe the oölitic limestone as "dull battleship gray, and the purest consists almost entirely of oölites about 2 mm in diameter, embedded in a matrix of smaller oölites averaging about 0.1 mm in diameter." Less pure varieties, which grade into tuffs and shales, are reported to be more common. A chemical analysis by A. C. Vlisidis (Bailey and Everhart, 1964, p. 24) of the oölitic limestone indicated 0.91% SiO_2 , 0.61% Al_2O_3 , 0.30% Fe_2O_3 , 0.77% MgO , 55.11% CaO , 0.10% TiO_2 , 0.31% P_2O_5 , 0.01% MnO and 42.24% CO_2 .

Bailey and Everhart (1964, p. 24) consider the oölitic limestone to offer "good commercial possibilities" because of the virtual absence of chert lenses. However, all of the limestone bodies of the Baldy Ryan drainage lie within a broad shear zone and are apt to be less continuous than indicated on Bailey and Everhart's map (plate 1).

Other reference: Bailey, Irwin, and Jones, 1964, p. 72–73.

Bernal deposit. Location: SE $\frac{1}{4}$ sec. 19 (proj.), T. 8 S., R. 2 E., M. D., 1 mile northwest of Coyote Peak and 3 miles west of Coyote; Los Gatos 15-minute quadrangle. Ownership: Mr. Gomez, Hollister(?) (1962).

Fragmental limestone and associated caliche or calcareous tufa ("marl") were utilized intermittently from 1915 to 1938 for beet-sugar refining and agricultural purposes. The deposit apparently was opened by Spreckels Sugar Company, which shipped a few thousand tons of limestone around 1915 to one of their refineries (Huguenin and Costello, 1920, p. 186). Under the ownership of Pedro A. Bernal, the California Lime Marl Fertilizer Company produced roughly 10 to 20 thousand tons of soft "marl" for agricultural use.

At the quarry, a coarse breccia of fragmental Eocene limestone is imbedded in varying amounts in a soft matrix of caliche or impure calcareous tufa. The deposit, which ranges from 5 to 15 feet thick or more overlies sheared sandstone at the south side of the quarry. Sandstone fragments and other impurities also are present in the carbonate matrix. It seems likely that the deposit is the result of landsliding or faulting in association with the surficial deposition of calcium carbonate. The Eocene age of the hard limestone is based on its abundant fossil debris (Bailey and Everhart, 1964, p. 69–71). It is gray to yellowish tan, dense to slightly vuggy, fine grained to medium crystalline, and locally is either sandy or argillaceous(?). A typical sample of the hard limestone, analyzed by

Lydia Lofgren of the California Division of Mines and Geology in 1962, showed 53.07% CaO, 85% MgO, 2.32% SiO₂, .40% Al₂O₃, .40% Fe₂O₃, .01% P₂O₅, and 42.55% ignition loss.

The soft matrix material is off white to yellowish-and reddish-brown, porous, impure calcium carbonate. This no doubt is the "marl" quarried and pulverized for agricultural use.

The deposit is exposed over a small area as low, scattered outcrops of hard limestone separated widely by soil. When examined in July 1962, development consisted of a shallow, irregularly benched quarry 200 to 300 feet in diameter. There has been no recent activity and future possibilities appear to be limited.

Bailey and Everhart (1964, plate 1) mapped the deposit as an east-west lens, 500 feet long by 125 feet in maximum width. They show three other lenses in SE $\frac{1}{4}$ sec. 19. The largest of these, lying 600 feet northeast of the Bernal deposit, measures 1,100 feet by 200 feet. It was developed by a trench 100 feet long by 15 feet wide, which exposes 8 feet of limestone breccia and caliche similar to that at the nearby quarry. The map shows several other deposits of Eocene limestone to the west. The largest of these, in sec. 20, T. 8 S., R. 2 E., is nearly half a mile long. It is exposed only as scattered limestone fragments in heavy soil and is not believed to represent a deposit of significant size or purity. The Eocene deposits examined in the Santa Teresa Hills have insufficient exposures to indicate much commercial potential. Indeed, two of the deposits are brecciated and impure where they were quarried.

Other references: Franke, 1930, p. 9; Lagon, 1947, p. 311-312; Davis and Jennings, 1954, p. 364.

Calero deposit. Location: Near center sec. 8 (proj.), T. 9 S., R. 2 E., M. D., 4 miles southwest of Coyote; Los Gatos 15-minute quadrangle. Ownership: E. M. Fellows (estate), 23201 McKean Road, Morgan Hill (1965).

This deposit lies a little more than a mile south of Calero Reservoir in a small valley a mile west of McKean Road. It is exposed as an arcuate, northwest-trending body of Franciscan limestone 1,800 feet long by an average of 200 feet wide (Bailey and Everhart, 1964, plate 1). The Calero deposit consists mainly of fine-grained to medium-crystalline, light- to dark-gray, thinly bedded, bituminous, locally brecciated limestone, commonly with interbeds of black chert. At the northwest end of the body, light-dove-gray, pink, and brownish-red varieties of limestone were observed (July 1962). Most beds exposed in the creek dip moderately northeast and southwest, although other dip directions are indicated at the extremities of the body. Abrupt changes in attitude, plus brecciated beds, suggest that the limestone body is broken by faults.

Judging from exposures near the quarry, the sequence of limestone beds is probably at least 50 feet

thick. If an average thickness of 50 feet is assumed, available reserves of limestone and chert would be in the order of a million tons. Future potential of the deposit is probably limited to crushed rock uses due to the dispersion of chert interbeds throughout the limestone.

A single quarry situated in the middle of the deposit on the north bank of the creek was worked prior to 1937, when E. M. Fellows acquired the property. The quarry is 75 by 20 feet in plan with a 30-foot face. The use of the quarried rock and other details of development are unknown. In 1962 the owner reported that the deposit was test drilled, but the results are unknown.

Castro Valley deposits. Location: Sec. 15 (proj.), T. 11 S., R. 3 E., and sec. 30, T. 11 S., R. 4 E., M.D., 3 to 4 miles southwest and south of Gilroy; San Juan Bautista 15-minute quadrangle. Ownership: Mainly Castro Valley Ranch (c/o H. S. Chase, Santa Barbara), Sargent Ranch, and Shoemaker (Bloomfield) Ranch (1963).

Numerous lenses of limestone, associated with other sedimentary and volcanic rocks of the Franciscan Formation, are shown on the northeast flank of the Santa Cruz Mountains by Allen (1946, plate 1). The lenses lie in two principal groups centering in S $\frac{1}{2}$ sec. 15 (proj.) and 3 miles to the southeast in and near SW $\frac{1}{4}$ sec. 30. Some of these deposits were examined briefly in July 1963. Scattered limestone bodies also lie to the north and east (Allen, 1946, plate 1).

The deposits in sec. 15 consist of a west-trending series of detached lenses and masses. The largest is a sinuous lens, roughly 1,500 feet long by 150 feet wide, that dips north into the hill. On hill "1722", a faulted mass 900 feet long by a maximum of 200 feet wide appears to merely cap the ridge and may be relatively thin. In sec. 30, the limestone bodies trend more to the northwest and are smaller than shown by Allen. The limestone observed in each area is generally dark gray, fine crystalline, bituminous, well bedded to platy, and somewhat siliceous. Other types of limestone are light gray or even dark gray mottled with white. All of the limestone is abundantly associated with thin interbeds of chert. Variable attitudes and common brecciation features reflect the widespread faulting that has disturbed and broken the many lenses. Some of the larger faults are shown by Allen (1946, plate 1).

Two or three tiny quarries, from which only a few tens of tons of material were removed, were developed in S $\frac{1}{2}$ sec. 30 many years ago for an undetermined purpose. A chemical analysis by Matti Tavela of the Division of Mines and Geology of typical mottled (brecciated), bituminous limestone from a quarry in SW $\frac{1}{4}$ sec. 30 showed 3.0% SiO₂, 0.60% Al₂O₃, 0.19% Fe₂O₃, 0.27% MgO, 51.8% CaO, 0.14% P₂O₅, and 43.0% ignition loss. Reserves of limestone may aggregate several million tons, but none of the individual masses appears to contain more than a few hundred

thousand tons of available limestone. The largest masses lie in SW $\frac{1}{4}$ sec. 15 and on hill "1722" in SE $\frac{1}{4}$ sec. 15. Future development would appear to be limited to supplying local markets with crushed rock.

Clark Ranch deposit. An undeveloped deposit of "hydraulic limestone" is reported 7 miles east of Madrone (Watts, 1890, p. 619; Logan, 1947, p. 312). Its exact location is unknown.

Guadalupe Creek (Guadalupe Lime Company) deposits. Location: Near SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 29 (proj.), T. 8 S., R. 1 E., M. D., 5 miles east of Los Gatos; Los Gatos 15-minute quadrangle. Ownership: Not determined (1962).

Several small deposits of cherty limestone of the Franciscan Formation lie 1,000 feet south of Guadalupe Creek. These were quarried by Guadalupe Lime Company as a source of lime from about 1864 to 1890 or a little later (Irelan, 1888, p. 543; Watts, 1890, p. 619; Crawford, 1894, p. 349). The limestone was developed through several small quarries and hauled "by trucks worked by a gravity pulley" to the kiln 400 feet below (Irelan, 1888, p. 543). Considerable hand-sorting evidently was necessary to remove the chert from the limestone. Production during the summer of 1890 was 150 barrels of lime per day (Watts, 1890, p. 619). There is no record of further production, but there is some evidence that more recent development work was carried out in the quarry areas. The Guadalupe Creek deposits may have been part of the holdings of San Jose Cement Company (which see).

The small, detached bodies of limestone that have been quarried form a closely spaced, northwest-trending group lying just southeast of the fourth "hairpin" curve of the paved access road. Other small limestone masses are shown to the southeast and northwest of that group by Bailey and Everhart (1964, plate 1) but are undeveloped. Altogether, the limestone extends discontinuously for 4,000 feet. Where developed, the deposits are largely covered with talus and quarry debris consisting mainly of light-gray, dense, fine-grained, sometimes siliceous limestone and gray to black, thin-bedded chert. Locally, dark-gray, white-mottled, crystalline limestone is present. According to Irelan (1888, p. 543), "dark-colored bituminous limestone" also is found, but such material was not observed during a brief visit in May 1962. The degree of fracturing, as well as the presence of secondary calcite, suggests the deposits may be broken by faults.

The deposits are developed by several small quarries over a length of 900 feet. Quarry development is too irregular to estimate total production accurately, but probably it is less than 50,000 tons.

Limestone reserves cannot be accurately determined without better exposures and some drill data, but available reserves do not appear to be large. Because of the presence of chert beds within the limestone, the deposit is useful chiefly as a local source of crushed rock.

Guadalupe Reservoir deposits. Location: Near SW $\frac{1}{4}$ sec. 33 (proj.), T. 8 S., R. 1 E., M. D., 6 miles east-southeast of Los Gatos; Los Gatos 15-minute quadrangle. Ownership: Not determined (1962).

A C-shaped mass of limestone of the Franciscan Formation was mapped by Bailey and Everhart (1964, plate 1) just west of Hicks Road at the upper end of Guadalupe Reservoir. The deposit is shown to be a maximum of 150 feet wide and 1,600 feet long. Bedding attitudes are not consistent with the mapped distribution of limestone, and it is likely that this modest-sized deposit is broken by faults and is possibly discontinuous. Small bodies of limestone also are shown by Bailey to lie nearby. The limestone is reported by Bailey (1962, personal communication) to be typical of the Franciscan Formation and it contains thin chert interbeds. There has been no commercial development, although some prospecting was done at the small limestone body near Hicks Road.

Kennedy Road deposit. Location: SW $\frac{1}{4}$ sec. 24, T. 8 S., R. 1 W., M. D., 3 miles east of Los Gatos; Los Gatos 15-minute quadrangle. Ownership: Not determined (1962).

A northwest-trending lens of Franciscan limestone 1,300 feet by a maximum of 150 feet is shown by Bailey and Everhart (1964, plate 1). The southeast end of the lens, where crossed by Kennedy Road, was examined briefly in July 1962. Here, the body consists of a somewhat faulted sequence of beds that dips moderately south and is about 100 feet thick. The upper half consists of typical light-gray, dense, foraminiferal limestone with thin chert interbeds. Limestone in the lower part is interbedded or otherwise mixed with sandstone and volcanic rock of the Franciscan Formation. The deposit is partly brecciated and recemented with calcite.

The deposit is undeveloped; it appears to be suitable mainly for crushed rock purposes. Maximum available reserves are probably less than 500,000 tons of limestone and associated rocks.

Los Gatos Lime Company deposit (Ellis; Douglas Ranch). Location: SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 27 (proj.), T. 8 S., R. 1 W., M. D., 1 mile southeast of Los Gatos; Los Gatos 15-minute quadrangle. Ownership: Lloyd Estate, c/o Tal and John Lloyd, 16140 Cypress Way, Los Gatos (1962).

Los Gatos Lime Company quarried limestone between 1886 and 1890, and most of it probably came from property owned by J. E. Ellis (formerly Douglas Ranch). The limestone was hauled 2 miles to a kiln in Los Gatos where lime was manufactured (Watts, 1890, p. 619). Some limestone also was sold for sugar refining (Irelan, 1888, p. 545-546). Several thousand tons of limestone shipped for sugar refining from the Los Gatos area in 1938 by Basic Limestone Products Company may also have come from this deposit (Logan, 1947, p. 312).

The deposit consists of three small limestone masses that extend southwestward for 1,500 feet. The largest of these is shown by Bailey and Everhart (1964, plate 1) to be faulted and to cover an irregular, northeast-trending area 600 feet by 275 feet in maximum dimensions. It consists of typical Franciscan limestone and moderate amounts of thin chert interbeds. At the quarry, the strata dip 20°–35° S and have an estimated exposed thickness of 30 feet. Here the limestone varies from fine grained, light gray, dense, and foraminiferal to dark gray, fine crystalline, and bituminous. Sandstone and volcanic rocks of the Franciscan Formation are in contact with the deposit on the north.

When examined in July 1962, the main limestone mass was developed by an irregular quarry 250 feet by 100 feet. It had been worked by two benches through a relief of about 80 feet. Roughly 10,000 to 20,000 tons of rock had been removed. Vegetation indicates the quarry has not been worked for at least 20 years. Two other quarries are indicated 800 feet and 1,200 feet to the southwest in a small lens (Bailey and Everhart, 1964, plate 1). These quarries were not examined but are probably small.

Because the limestone bodies are small and commonly contain chert interbeds, future use of the limestone appears to be limited to crushed rock.

Other references: Crowford, 1894, p. 394; Aubury, 1906, p. 82–83; DAVIS and Jennings, 1954, p. 364.

Lyndon deposits. Location: S½ sec. 28, T. 8 S., R. 1 W., M. D., 1 mile south of Los Gatos; Los Gatos 15-minute quadrangle. Ownership: Guadalupe College (?), Los Gatos (1962).

The Lyndon deposits lie on St. Josephs Hill, mainly in NW¼ SE¼ sec. 28. As mapped by Bailey and Everhart (1964, plate 1), the deposits consist of a number of small lenses of Franciscan limestone extending over an area half a mile long by 1,000 feet wide. The largest lens is about 700 feet long and a little more than 100 feet wide at its maximum. It consists of light-gray, fine-grained, foraminiferal, somewhat siliceous limestone with lesser amounts of fine crystalline, dark-gray, bituminous limestone. Chert interbeds are common throughout the limestone and may comprise a quarter of the deposit. The strata show variations in attitude and probably are faulted. The deposit was developed by a narrow hillside quarry about 200 feet long with a 20-foot face (visited July 1962). Production, which amounted to only a few thousand tons, was made many years ago judging from the considerable plant growth. A small quarry, 700 feet to the southeast, exposes another small lens. It is not known who worked these deposits, but it may have been the Los Gatos Lime Company (which see).

Below the Franciscan limestone outcrops, Eckel (1933, p. 356, 359) noted a large deposit of travertine as much as 30 feet thick. Apparently it is undeveloped.

Other reference: Davis and Jennings, 1954, p. 364, 408.

Mindego deposits. Location: Mainly secs. 7, 18, 19, T. 7 S., R. 3 W., and sec. 15, T. 8 S., R. 3 W., M. D., 1½ to 3 miles east, 1 mile west and 8 miles southeast of La Honda; Half Moon Bay and Ben Lomond 15-minute quadrangles. Ownership: Not determined.

Thin beds and lenses of limestone are reported in the Mindego Formation (Oligo-Miocene) at several localities near La Honda and southeast of that settlement. These deposits are described by Cummings *et al.* (1962, p. 192) as follows:

"Some of these are calcarenites overlying volcanic strata. Many are bioclastic in origin and consist largely of fragments of small pelecypods and bryozoa. For example, along Waterman Creek in sec. 15, T. 8 S., R. 3 W., one of these limestone lenses is more than 1,000 feet long and nearly 100 feet thick and is composed chiefly of broken and compacted oyster shells. Other limestones occur near the summits of Mindego and Longley Hills and in San Gregorio Creek in the vicinity of Redwood Terrace."

These same deposits were described as "limestone inclusions" and "clastic dikes" of Eocene age by Branner *et al.* (1909, p. 3, 8–9, map).

None of these occurrences is known to be of economic value, although the Waterman Creek deposit appears large enough to warrant further investigation. The chemistry of the limestone is not known, except that tuffaceous debris is reported to be common.

Monte Bello Ridge deposits (including Bond, Winship, Black Mountain). Location: E½ T. 7 S., R. 3 W., and SW¼ T. 7 S., R. 2 W., M. D., 5 to 8 miles south and southwest of Los Altos; Palo Alto 15-minute quadrangle. Ownership: Multiple—includes Kaiser Cement and Gypsum Corp., National Realty Co., Mary I. Crocker, Winship Estate, G. F. and A. Morrell, Emmet Burns, and many others (1962).

The Monte Bello Ridge deposits form a group of numerous, small to medium-sized limestone bodies that extends southeastward for 7½ miles from a point west of Page Mill Road in NW¼ sec. 10., T. 7 S., R. 3 W., to Stevens Creek near S¼ cor. sec. 33, T. 7 S., R. 2 W. The deposits lie on the northeast side and within 1½ miles of the San Andreas fault, which obliquely truncates the northwest end of the group. Part or all of the deposits have been mapped by several geologists, but the only published maps are by Walker (1950b, plate 1) and Dibblee (1966b). Part of Dibblee's map is reproduced in figure 3. Included in the Monte Bello Ridge group of deposits are the properties of Bond (Franke, 1930, p. 9) and Winship (Huguenin and Costello, 1920, p. 185), as well as most of the deposits on Black Mountain (Permanente deposit excepted). There has been no commercial development of the limestone although considerable trenching and core-drilling was conducted within 1½ miles of Black Mountain by Permanente Cement Company (now Kaiser Cement and Gypsum Corporation), mainly about 1945.

Figure 3. Map of Permanente and Monte Bello Ridge limestone deposits.

The limestone on Monte Bello Ridge occurs as lenticular, discontinuous masses in a thick sequence of volcanic and sedimentary strata of the Franciscan Formation. The strata dip predominantly northeast but in many places are vertical or overturned to the southwest (Dibblee, 1966b). Evidence of faulting is prevalent throughout the area, and some minor faults offset some of the limestone lenses. The limestone everywhere is associated with thin chert interbeds. Most lenses of the limestone and chert are less than 50 feet thick and seldom as thick as 100 feet. However, the lens in NE¼ sec. 29 is reported to be as much as 200 feet thick and to dip vertically (Dibblee, 1965, oral communication). The limestone is typical of the Franciscan Formation, varying from light gray, fine grained, and foraminiferal to dark gray, fine to me-

dium crystalline, and bituminous. Silica in chert beds, as well as distributed interstitially with the calcite, constitutes the principal impurity. The maximum grade of selected limestone samples is indicated by analyses in Franke (1930, p. 9, 10) and Huguenin and Costello (1920, p. 185). Four analyses (made by Abbot A. Hanks, Inc., in 1956) of selected samples from the Burns Ranch in sec. 15—containing 51.3–54.1% CaO, 0.2–0.5% MgO, 0.8–4.5% SiO₂, and small percentages of Fe₂O₃, Al₂O₃, and P₂O₅—are rather typical of the Monte Bello Ridge limestone deposits.

Reserves of limestone no doubt aggregate many millions of tons, but none of the deposits appears to be very large. Furthermore, many of them dip steeply into the ridge, thereby limiting the available reserves. The apparent small size and discontinuous nature of

the deposits has been verified to some extent by drilling and trenching in the vicinity of Black Mountain. Little exploration has been done elsewhere. Considering the relatively small size of the deposits and the presence of chert interbeds, it is probable that the limestone will be useful only for crushed rock purposes.

Other reference: Logon, 1947, p. 312, 317.

Permanente (Black Mountain) deposit. Location: W $\frac{1}{2}$ sec. 17 and E $\frac{1}{2}$ sec. 18, T. 7 S., R. 2 W., M. D., 4 miles south of Los Altos; Palo Alto 15-minute quadrangle. Ownership: Kaiser Cement and Gypsum Corporation, 300 Lakeside Drive, Oakland (1965).

The Permanente deposit is situated mainly on a steep slope on the north side of Permanente Creek, $1\frac{1}{2}$ miles east of Black Mountain. It is by far the largest limestone body known in the Franciscan Formation and may contain the largest reserves of any limestone deposit in the central Coast Ranges. Initial development of this deposit apparently began around 1900, when El Dorado Sugar Company selectively quarried high-grade limestone for use in beet-sugar refining (Aubury, 1906, p. 82). Later, Alameda Sugar Company quarried limestone which was shipped to Alviso, where it was calcined for use in sugar refining (Huguenin and Costello, 1920, p. 185). Santa Clara Holding Company acquired the deposit during the 1920s, but records indicate that they produced limestone (for lime) only in 1934. Large scale production of limestone began in 1939 when Permanente Cement Company established a plant to supply 6,800,000 barrels of cement for the construction of Shasta Dam. Expansion over the years has increased plant capacity from $2\frac{1}{2}$ million to $8\frac{1}{2}$ million barrels of cement per year. Production of limestone and associated materials has increased to more than 2 million tons per year. Most of this has gone to make cement, but significant amounts of overburden and low-grade limestone are sold commercially for aggregate and road construction uses. Until 1951, the company also sold high-grade limestone for use in beet-sugar refining. Increasing percentages of low-grade limestone encountered in recent years stimulated Permanente Cement Company to explore ways to beneficiate the limestone. They completed a froth flotation plant in 1962; and, according to Kleiber and Meisel (1964), this plant was operating successfully by 1963. In 1964, the company changed its name to Kaiser Cement and Gypsum Corporation.

The limestone deposit at Permanente Creek covers an irregular triangular area having a maximum length of a mile and a maximum width of two-thirds of a mile (fig. 3). It is exposed through 800 feet of relief and may be as much as 700 feet thick in places (Kleiber and Meisel, 1964, p. 39). The limestone body, which contains early Late Cretaceous microfossils, is associated with altered volcanic rocks (greenstone) and sedimentary rocks of the Franciscan Formation. Structurally

the limestone body is complicated by faults and folds, but mainly it dips 25° to 35° SE. Moderate northeast dips in the south part of the mass indicate the deposit to be an eastward plunging syncline whose axial trace lies just north of Permanente Creek.

Internally, the deposit consists of thin beds of light and dark limestone which tend to occur in mutually exclusive sequences. Thin layers and lenses of chert are interbedded in varying amounts with both types of limestone. A thick sill or flow of volcanic rock, now altered to greenstone, and a few thin tuff beds also are present in the quarry area. The stratigraphic relations of these different beds and sequences is not clearly understood, as extensive faulting has severely disrupted the deposit. G. W. Walker (1950b) interpreted the stratigraphic sequence to consist of an "upper light" limestone unit, a "blue" limestone unit, and a "lower light" limestone unit. A more recent interpretation, based on extensive drill data and chemical analyses, was given by Donald Towse of Kaiser Cement and Gypsum Corporation in a paper presented at the American Institute of Mining, Metallurgical, and Petroleum Engineers, Southwest Mineral Industry Conference, Las Vegas, Nevada, April 24, 1961. According to Towse, the deposit consists of only two limestone units—an upper light-colored unit at least 300 feet thick and a lower dark gray unit at least 200 feet thick. The light limestone is split near its middle by a 90-foot thick greenstone sill or flow. These units may be sliced by two or three thrust faults, causing widespread repetition and omission of strata. Further complexities resulted from later folding and high-angle faulting.

The light limestone is typically light gray to dove gray, fine grained, dense, foraminiferal, and well bedded. Light and dark interlayers of chert, 1 to 3 inches thick, constitute 10 to 50% of the light unit, being more prevalent near the base. The dark limestone is blue gray to dark gray but weathers and bleaches to lighter shades of gray. It is very fine to medium crystalline, bituminous, and well bedded to platy. Black chert interbeds are common but not as abundant as in the light limestone. Both types of limestone are strongly fractured.

The chemical grade of the limestone is quite variable, with high and low grades occurring in both the light and dark units. The variations in grade are reflected to some extent in the bulk analyses presented in table 8. According to Towse, the dark limestone averages 87% CaCO_3 and the light limestone 67% CaCO_3 , the upper part of the light limestone being the best quality (also see Bailey, Irwin, and Jones, 1964, p. 70). For purposes of quarry development, three qualities of limestone are recognized by Kaiser Cement and Gypsum Corporation (Kleiber and Meisel, 1964, p. 39): 1) high grade—consists of dark limestone and averages 87 to 88% CaCO_3 ; 2) medium grade—a mixture of light and dark limestone running 70 to 82% CaCO_3 ; and 3) low grade—mainly extremely cherty, light-colored limestone containing 55 to 70% CaCO_3 .

Table 8. Bulk analyses of limestone from the Permanente deposit, Santa Clara County (Bailey and Everhart, 1964, table 6).

	1	2	3	4	5	6	7	8	9	10
SiO ₂	29.23%	18.4%	17.5%	16.7%	15.9%	15.2%	13.4%	11.3%	7.24%	4.18%
Al ₂ O ₃	1.26	1.5	1.4	1.5	1.5	1.5	1.4	1.3	0.60	0.66
Fe ₂ O ₃	0.54	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.42	0.32
CaO	38.04	43.3	43.8	44.4	44.9	45.4	46.4	47.8	50.96	52.74
MgO	0.24	0.3	0.4	0.3	0.4	0.4	0.4	0.3	0.04	0.05
Loss on ignition	30.66	34.3	34.7	35.1	35.7	36.1	37.1	38.3	40.48	41.90
Total	99.97	98.5	98.5	98.7	99.1	99.3	99.3	99.6	99.74	99.85
CaCO ₃	68.4	77.3	78.2	79.3	80.2	81.0	82.9	85.3	91.39	94.67

1, 9, and 10 from Logan, 1947, p. 315.

2-8 obtained from Permanente Cement Co. by E. H. Bailey and D. L. Everhart

Normally the low-grade limestone, which is interbedded with the higher grades, would be wasted. However, by means of differential grinding and froth flotation, the low-grade rock is sufficiently up-graded to be blended into the raw feed for cement.

Quarry operations at the Permanente deposit are conducted by benching, at 50-foot intervals, in one large pit near the center of the deposit. An older abandoned quarry is located in SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 18 at the west end of the deposit. In 1962, the main quarry covered an area about 1,800 feet by 1,500 feet. There

was about 500 feet of relief between the highest face and the quarry floor, the latter being at an elevation of 1,350 feet. Quarry control is provided by exploratory (rotary) drilling on 100-foot or 100-foot by 200-foot centers. Deep diamond drilling also is used for long-range planning.

Normal open-pit operations prevail, with selective quarrying employed to maintain the proper grades of limestone. Blast holes are made with air-circulated rotary drills. Ammonium nitrate and oil constitute the explosive. Some secondary blasting is necessary. Electric-powered shovels load 45-ton-capacity dump trucks, which haul to primary crushers at the edge of the quarry floor. The material is then crushed and transferred to secondary crushers near the plant via a 4200-foot belt conveyor. After secondary crushing, the limestone is conveyed to separate stockpiles to await further processing. Weathered greenstone, obtained west of the quarry and used to supply the needed alumina and iron in cement, also is stockpiled here. Formerly, the alumina-iron oxide fraction was supplied by purchasing laterite produced in Amador County.

Photo 6. View to west of large multi-benched quarry at Permanente limestone deposit, 1969. The quarry is developed in chert-bearing limestone (Franciscan Formation), which is the principal raw material used at the nearby cement plant. Photo courtesy of Kaiser Cement and Gypsum Corp.

Photo 7. Aerial view of Kaiser Cement and Gypsum Corporation's cement plant at Permanente in 1969. The plant, which is the largest in the west, has six kilns and an annual capacity of 8,500,000 barrels of cement. Photo courtesy of Kaiser Cement and Gypsum Corp.

The various raw materials are further crushed, ground, beneficiated, and blended to make up the raw feed (slurry). The feed is processed wet in six kilns, ranging from 44 feet to 45 feet long, to obtain the clinker. This is later ground with gypsum from Mexico to produce a variety of cement products. In addition to cement, the operator has produced crushed rock for use in concrete aggregate and road construction for many years. Such material has come from overburden and low-grade limestone. A sand by-product, derived as tailings from the flotation circuit, also is recovered for commercial sales (Kleiber and Meisel, 1964, p. 44).

Total production of limestone and associated chert at the Permanente deposit is estimated to be on the order of 40 million tons. Proved and estimated reserve figures are not available, but deep diamond-drilling indicates that reserves considerably exceed past production.

Other references: Franke, 1930, p. 9; Krivari, 1942, p. 374-397; Logan, 1947, p. 313-317; Davis and Jennings, 1954, p. 355-358, 361, 364-366; Bowen and Gray, 1962, pt. 2, p. 4; Bailey and Everhart, 1964, p. 24.

San Jose Cement (Guadalupe Portland Cement) Company formerly owned a "deposit of 331 acres of undeveloped limestone" in secs. 4 and 5, T. 9 S., R. 1 E., and sec. 32, T. 8 S., R. 1 E., M.D. (Franke, 1930, p. 9-10). This property probably included the Guadalupe Reservoir deposit (which see). The company lapsed as a corporation in 1936 (Logan, 1947, p. 313).

Snell Ranch deposit. Location: $2\frac{1}{2}$ NE $\frac{1}{4}$ sec. 28, T. 8 S., R. 1 W., M.D., 1 mile southeast of downtown Los Gatos; Los Gatos 15-minute quadrangle. Ownership: J.A. Snell, Foster Road, Los Gatos (1962).

This deposit of Franciscan limestone is shown by Bailey and Everhart (1964, plate 1) to be an east-west lens 1,300 feet long by a maximum of 200 feet wide. Where exposed along Foster Road, the deposit is at least 25 to 30 feet thick and dips gently to moderately south. It is composed mainly of dark, fine-crystalline, somewhat mottled, bituminous, thinly bedded limestone that appears to be brecciated and recemented with calcite. A chemical analysis by Matti Tavela in 1963 of typical limestone from the quarry showed 1.3% SiO₂, 0.60% Al₂O₃, 0.37% Fe₂O₃, 0.35% MgO, 53.9% CaO, 0.10% P₂O₅ and 42.8% ignition loss. Light dove-gray, fine-grained limestone is present in lesser amounts. Thin interbeds of dark chert constitute the main visible impurity.

The deposit was developed by a tiny quarry west of the road, from which less than 1,000 tons of material was excavated. The date or purpose of development is unknown, although it is possible that this limestone was used by Los Gatos Lime Company (which see).

Wright's Ranch deposit. Location: probably sec. 16 (proj.), T. 9 S., R. 2 E., M.D., 5 miles southeast of New Almaden mine; Los Gatos 15-minute quadrangle. Ownership: Not determined.

"A large and valuable deposit of marble" is described by Crawford (1894, p. 394). It is exposed continuously over an area 60 feet to more than 100 feet wide and more than 3,000 feet long. The limestone is usually light gray but occasionally is tinged with red or brown. Some is nearly white, "but it is mostly mottled or curiously marked by blotches and streaks of light shades in the darker crystalline ground-mass." Crawford indicates the deposit to be of limited development, although some stone apparently was quarried.

This deposit probably is included in the mile-long, northwest-trending group of limestone lenses mapped as part of the Franciscan Group by Bailey and Everhart (1964, plate 1) in sec. 16 (proj.), by T. 9 S., R. 2 E. The largest of these lenses is shown to be a thin, sinuous body less than 100 feet thick, 1,200 feet long, and dipping steeply to the southwest.

Other reference: Logan, 1947, p. 317.

Unnamed deposits (near Chesbro Reservoir). Location: Approx. sec. 23 (proj.), T. 9 S., R. 2 E., M.D., north of Chesbro Reservoir and 3 miles west of Morgan Hill; Morgan Hill 15-minute quadrangle. Ownership: Not determined.

Bailey and Everhart (1964, p. 21) mention the occurrence of limestone in the Franciscan Formation 2 miles south of the mouth of San Bruno Canyon. By way of comparison, they state that the "limestone crops out in more continuous exposures" than in the adjacent Santa Teresa Hills quadrangle to the west (see Bailey and Everhart, 1964, plate 1). Some limestone (possibly the same as above) also is reported along Llagas Creek in the Morgan Hill quadrangle (Bailey, Irwin, and Jones, 1964, photo 33). Neither of these deposits was examined by this writer.

SANTA CRUZ DISTRICT (B-5)

The Santa Cruz district covers those deposits in the Ben Lomond Mountain-Santa Cruz area of Santa Cruz County. Limestone has been produced continuously in this district since 1851, when Davis and Jordan first established a quarry and lime kiln near Santa Cruz. Although accurate records are not available, total limestone production is estimated to be close to 30 million tons. The San Vicente deposit of Pacific Cement and Aggregates, Inc., yielded about 25 million tons of limestone, most of which went into the manufacture of cement. It is estimated that 3 or 4 million tons of lime rock were calcined from 1851 to 1947. Crushed limestone for livestock feed, agricultural use, riprap, and other purposes also was produced in substantial amounts.

With one possible minor exception (see Wagner's Park deposit), all of the limestone is recrystallized and occurs as massive beds associated with schist and other metamorphic rocks which are commonly correlated with the pre-Cretaceous metamorphic Sur Series of the Santa Lucia Range in Monterey County. Granitic

rocks of probable Cretaceous age commonly intrude the metamorphic rocks. The principal limestone deposits are found northwest of Santa Cruz, west of Felton, and northeast of Davenport. Substantial limestone reserves appear to exist in each of these areas. Silica is the principal impurity at most deposits although magnesia causes problems locally. Schist interbeds and granitic dikes are common enough to cause a significant waste factor at most deposits. Nonetheless, most of the deposits appear to be sufficiently large and pure to warrant further exploration as potential sources of limestone.

In 1964, the only active limestone deposits were the San Vicente (Pacific Cement and Aggregates, Inc.), Pacific Limestone Products Company, and Holmes deposits. These and other known deposits are described alphabetically below.

Bonnie Doon deposit. Location: SW $\frac{1}{4}$ sec. 25, SE $\frac{1}{4}$ sec. 26, and NW $\frac{1}{4}$ sec. 36, T. 10 S., R. 3 W., M.D., 3 miles east-northeast of Davenport; Ben Lomond 15-minute quadrangle. Ownership: Mainly Pacific Cement and Aggregates Division, Lone Star Cement Corporation, 400 Alabama Street, San Francisco (1963).

The deposit has been quarried to a minor extent in NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 26 by Hinds and Packard, who calcined lime between 1890 and 1900. Remnants of their stone kiln and small quarry site can still be seen just east of Bonnie Doon road. This property was later acquired by Cowell Lime and Cement Company, which never worked the deposit. The S.H. Cowell Foundation now holds the property. The main limestone outcrops to the southeast, in secs. 25 and 36, are on land belonging to Pacific Cement and Aggregates. Other than extensive diamond drilling in SW $\frac{1}{4}$ sec. 25 done by the present owner during 1959 and 1960, this portion of the deposit is undeveloped.* Also, two prospect tunnels are shown on the Davenport 7 $\frac{1}{2}$ -minute quadrangle (1959 ed.) in SW $\frac{1}{4}$ sec. 25.

The Bonnie Doon deposit consists of one or more bodies of crystalline limestone and is intermittently exposed over a northwest-trending area 3,500 feet long and as much as 1,500 feet wide. Miocene sedimentary rocks overlap the deposit on most sides, concealing the true extent of the deposit. The approximate distribu-

tion of limestone is shown by Branner *et al.* (1909, maps) and Clark (1970). The limestone is white to gray and generally coarse crystalline, but some is fine crystalline and may be dolomitic or siliceous. Analyses of two samples from the Bonnie Doon quarry show 94% and 95.87% CaCO₃ and 2.8% and 2.93% MgCO₃ respectively (Eckel, 1933, p. 353). Some schist interbeds and granitic dikes occur locally with the limestone. Limestone reserves are difficult to assess because soil and vegetative cover mask the continuity between outcrops. The deposit is well disposed for open-quarry development, the outcrops occurring over 600 feet of relief. Proximity of Bonnie Doon and Smith Grade roads render good accessibility.

Pacific Cement and Aggregates recently drilled about 30 exploratory holes in SW $\frac{1}{4}$ sec. 25, mainly above an elevation of 1,000 feet. Although some minor schist beds were encountered, approximately 7 $\frac{1}{2}$ million tons of limestone reserves reportedly were developed. The company contemplates utilizing this deposit as a future source of limestone for its Davenport cement plant, which is 6 to 7 miles away by road.

Cowell Home Ranch deposits. Location: Secs. 2, 3, 9, 10, 11, 14 (proj.), T. 11 S., R. 2 W., M.D., 1 $\frac{1}{2}$ to 3 miles west and northwest of Santa Cruz City Hall; Santa Cruz and Felton 7 $\frac{1}{2}$ -minute quadrangles. Ownership: University of California at Santa Cruz and S.H. Cowell Foundation, 25 California Street, San Francisco (1963).

The Cowell Home Ranch deposits were first developed by I. E. Davis and A. P. Jordan who established a lime plant and quarry in 1851 (Logan, 1947, p. 318-319). The kiln was located near NW cor. sec. 14, just west of the present ranch house. Limestone immediately to the south and within half a mile to the north of the kiln area was the early source of lime rock. Later, Davis joined with Henry Cowell and continued operating the deposits through the 1880s. During this period, additional quarries and kilns were established 1 $\frac{1}{2}$ miles to the west in sec. 9 at the Wilder Creek-Cave Gulch deposit. About 1895 Cowell acquired sole ownership of the limestone property and formed the Henry Cowell Lime and Cement Company. By the early 1900s, Cowell controlled nearly all of the limestone reserves in the vicinity of Santa Cruz and some of the deposits near Felton and Bonnie Doon (see IXL and Bonnie Doon deposits). The early quarries on the Home Ranch eventually were closed down, and most of the limestone produced after about 1910 came from the quarry in SE $\frac{1}{4}$ sec. 3. Continuous kilns were erected at Rincon Station to burn this limestone; but only the dense finer crystalline limestone could be effectively processed, the coarse crystalline white limestone being burned in pot kilns near the ranch house (Huguenin and Costello, 1920, p. 237). About 1920, pot kilns were erected at Rincon Station and, thereafter, all the limestone was burned at the new facilities. Other quarries in secs. 2 and 11 were operated less

* Development of this deposit was completed in mid-1970 to supply limestone—formerly supplied by the San Vicente Creek deposit—to the PCA cement plant at Davenport. The company reports (Herb Gaskin, 1971, personal communication) that the new quarry is located in SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 25, T. 10 S., R. 3 W., nearly 3 miles east-northeast of the plant. The floor of the quarry is at an elevation of 800 feet. The multi-benched face is worked downward in a manner similar to that at the San Vicente Creek quarry. A maximum overburden of 100 feet is anticipated as the quarry is developed northeastward. After quarrying, the crystalline limestone is crushed in a semiportable plant (1,140-ton-per-hour capacity) and stored in a large concrete silo prior to a 3-mile belt-conveyor trip to the cement plant. Shale from a new quarry in the Monterey Formation (?) provides much of the alumina and silica needed to make cement. This quarry is situated along the conveyor route, halfway between the cement plant and limestone quarry, in sec. 34. The new crushing-storage-transfer facilities cost \$7 million to install. Capacity of the conveyor is 1,000 tons of limestone or 630 tons of shale per hour.

extensively, but it is not known when they were developed. The Cowell Lime and Cement Company ceased operating about 1947. Prior to that, the Cowell Home Ranch deposits had been utilized as a source of lime rock continuously for 96 years, with the possible exception of a few years prior to 1900. The only production in recent years was in 1956 and 1957 when Granite Rock Company produced a large amount (200,000 tons reportedly) of limestone for riprap from the quarry located in W¼ cor. sec. 11.

The Home Ranch deposits consist of numerous small to moderately large bodies of crystalline limestone associated with schist and other metamorphic rocks similar to the Sur Series of the northern Santa Lucia Range. Locally, the metamorphic rocks are cut by granitic rocks of Cretaceous age. Although bedding features are generally obscure, wide variations in bedding attitudes as well as common breccia features indicate the limestone masses to be considerably disrupted by faulting. Young sedimentary strata and heavy soil cover the limestone in many areas, making it difficult

to ascertain the extent of the various deposits; some of the limestone bodies may be larger than indicated on the accompanying map (figure 4). The limestone ranges from fine to very coarse crystalline and from nearly white to gray and blue gray, sometimes being banded or mottled. In many places, schist or quartzitic rocks are interlayered with the limestone; and, locally, granitic dikes and quartz veins cut the limestone. Aside from the noncarbonate rocks associated with the deposits, the main impurities in the limestone appear to be silica and silicate minerals. Dolomite rock was not identified in these deposits but may be present locally. Results of chemical analyses are presented in table 9. Other analyses are given in Eckel (1933, p. 353).

The several deposits and quarries that lie on the Cowell Home Ranch were examined briefly by this writer in July and August 1963. They are described below by letter designation (A, B, C, D, E, F), the letters corresponding to those shown on the map (figure 4).

Figure 4. Map of limestone deposits near Santa Cruz.

Photo 8. Looking northeast at Pacific Cement and Aggregates' San Vicente Creek deposit, operated until 1970. Ancient crystalline limestone is overlain by Miocene sandstone and shale (upper bench). Limestone blasted from quarry benches was moved to glory holes at quarry floor and transferred underground to a rail system for 3-mile haul to cement plant for further crushing and processing. Photo courtesy of Pacific Cement and Aggregates Div., Lane Star Cement Corp.

Photo 9. Pacific Cement and Aggregates' cement plant west of Santa Cruz. Limestone and shale from nearby deposits are used to manufacture cement by the dry process. Pier (lower right) was used formerly to ship cement by ocean vessel; cement is now hauled by truck. Photo courtesy of Pacific Cement and Aggregates Div., Lane Star Cement Corp.

Deposit A. A sinuous line of outcrops is exposed more or less continuously along an unnamed creek for 6,000 feet between NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 14 and NW cor. sec. 11. Although 5 to 10 feet of soil overburden masks the limestone on both sides of the creek, the westerly strike of the bedding in places indicates the deposit locally might extend farther east and west than is shown on the map. The character of the limestone is quite variable in texture and color, and some is siliceous. At the south end, two small quarries are developed in limestone that is predominantly blue gray and medium crystalline. A few hundred feet to the north, near the old stone kiln remnants, fine- and coarse-crystalline, off-white to light-gray types of limestone are found. Obscure planar structures suggest a N 75° W strike with a vertical to steep south dip. Farther north in SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 11, bold outcrops of fine- to extremely coarse-crystalline, white- to blue-gray, high-calcium to highly siliceous limestone exist. At a tiny quarry near the south end of the outcrops, a 2-foot-thick interbed of schist indicates that at least part of the deposit is flat-lying. The area was explored by diamond drilling in 1955 by Marquette Cement Company.

The most extensively developed part of Deposit A lies near W $\frac{1}{4}$ cor. sec. 11. Here, the predominant types of limestone are: 1) off white, coarse crystalline with occasional gray bands, and 2) gray, fine to medium crystalline. Results of chemical analyses of each of these rock types are given in table 9. Sample CH-2 indicates the white limestone to be of high quality, but sample CH-1 shows about 3 percent each silica and magnesia to be present in the gray rock. The main quarry is nearly 1,000 feet long, 50 to 300 feet wide, and has a maximum face of 60 or 70 feet. An estimated 300,000 tons of limestone has been quarried here; two-thirds of this reportedly was used for riprap along the San Lorenzo River about 1956-57. Other small quarries may have been developed elsewhere in the deposit but were not recognized.

Deposit B. Located mainly in SE $\frac{1}{4}$ sec. 3, this deposit has provided the main source of lime-rock for Cowell since about 1910. The deposit is about 900 feet long, at least 300 feet in maximum width, and is exposed through a total relief of about 100 feet. A little schist is exposed on the south wall, and thin streaks of biotite-garnet schist have been penetrated by drill holes. The deposit appears to dip gently to steeply south and may be broken to some extent by faults. As much as 10 feet of soil overburden plus vegetation and quarry debris tend to conceal the areal extent of the deposit. Diamond drilling conducted by Marquette Cement Company in 1955 reportedly penetrated limestone, with only thin streaks of foreign matter, to a depth of 200 feet. Most of the limestone is off white to light gray with some dark gray banding, coarse crystalline, and locally graphitic. The high calcium content of the limestone is reflected in the analyses of 5 samples—CH-3 and 4; SACR-1 to 3—given in table 9.

It is interesting to note the consistent differences in contents of MgO, SiO₂, Al₂O₃, and P₂O₅ reported for the two groups (SACR, CH) of samples. The differences probably reflect the analytical methods employed by the analysts more than the chemistry of the samples.

Deposit B is developed by an irregularly benched pit-quarry with maximum dimensions of about 800 feet by 300 feet by 100 feet. It is estimated that 500,000 to 1 million tons of limestone were produced from this deposit prior to 1947. Most of this was hauled to kilns at Rincon for calcining. Since 1947, only minor amounts of rubble and architectural stone have been taken. Additional quarrying apparently was conducted immediately to the southeast, but quarry debris masks any limestone that may have cropped out in that area.

Deposit C. This deposit consists of limestone exposed intermittently over an elliptical area 1,700 feet by 1,100 feet in NW $\frac{1}{4}$ sec. 11. Much of the limestone is coarse to very coarse crystalline, white to light gray, and high calcium. It is interbedded with schist to some extent and is overlain to the east by gently dipping beds of Miocene sandstone. Crude bedding in some places indicates that stratification dips 55 to 65° N; but some variations in dip, as well as brecciation features, suggest that the deposit is structurally complicated. Although the relative proportions of limestone and schist are not known, the deposit is exposed through 300 feet of relief and contains at least several million tons of limestone. The deposit is developed by an old hillside quarry approximately 120 feet by 60 feet with a maximum face of 50 feet. It is accessible by a dirt road from the north.

Deposit D. Located in the SW $\frac{1}{4}$ sec. 2, this deposit appears to have a westerly elongation of more than 500 feet and a maximum width along the road of 300 feet. It consists of coarse-crystalline, off-white to gray, banded limestone with some very coarse-crystalline white limestone. Biotite schist borders the deposit on the north; the other boundaries are masked by soil and heavy vegetation. Near the quarry, the apparent stratification dips steeply south. The deposit was worked many years ago by means of an open quarry about 100 feet in diameter with a maximum face of 30 feet.

Deposit E. Situated in SW $\frac{1}{4}$ sec. 2, a few hundred feet north of deposit D. It was tentatively mapped by G. W. Leo (1967 and unpublished Stanford thesis) as an elliptical mass 1,400 feet long by 700 feet wide. Limestone outcrops and float a few hundred feet to the east may be an extension of the deposit. Much of the limestone at the quarry is fine to medium crystalline and light to medium gray; however, some is coarse crystalline and white to gray. The attitude of the deposit is not known, and the mass appears to be broken by faulting. Details of the deposit are concealed by

dense vegetation and soil overburden. The deposit was worked through an open-faced quarry 300 feet by 150 feet with a maximum face of 70 feet. Heavy overgrowth indicates the quarry has not been worked for at least 30 to 40 years. Production is estimated to have been on the order of 100,000 tons. The remains of old stone kilns can be seen along the dirt road just south of the deposit.

Deposit F. Includes the extensive limestone exposures along the Wilder Creek-Cave Gulch drainage in SW $\frac{1}{4}$ sec. 3, E $\frac{1}{2}$ sec. 9, and W $\frac{1}{2}$ sec. 10. As mapped by G. W. Leo (1967 and unpublished Stanford thesis), the limestone crops out over an irregular, sinuous area a mile long and 600 feet to 1,500 feet wide. The limestone is poorly exposed but appears to be interbedded with schist and quartzite to some extent and cut locally by granitic dikes. Variable bedding attitudes suggest that the limestone exists as several discontinuous sequences or masses. The best quality limestone appears to be centered along Cave Gulch at the northeastern end of the deposit. Much of this limestone is high calcium, coarse crystalline, and off white to light gray with faint gray streaks or bands. Only a few small dikes of granitic rock penetrate the limestone in that area. Chemical analyses of samples (CG-1 and 2, table 9) show the variations in the better quality limestone found in the Cave Gulch area along Empire Grade. In the western part of the deposit (near the quarries in sec. 9), the limestone is more variable, being off white to gray, fine to very coarse crystalline, and locally siliceous. Some schist interbeds were noted, and granitic dikes and quartz veins exist locally.

Table 9. Chemical analyses of typical limestone samples from the Cowell Home Ranch, Halmes, and IXL deposits, Santa Cruz district.

Sample	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	P ₂ O ₅	Ign. loss
CH-1	3.00%	0.34%	0.13%	48.50%	3.20%	0.07%	0.10%	43.3%
CH-2	1.10	0.00	0.09	54.10	0.77	0.00	0.01	43.1
CH-3	1.70	0.00	0.07	53.40	0.50	0.00	0.11	43.3
CH-4	1.60	0.00	0.07	54.10	0.42	0.00	0.09	43.4
CG-1	2.60	0.60	0.19	52.30	0.88	ND	0.03	43.3
CG-2	0.80	0.25	0.09	54.20	0.14	ND	0.05	43.4
SACR-1	0.22	0.11	0.04	54.56	0.93	ND	tr	ND
SACR-2	0.20	0.12	0.06	53.80	1.52	ND	tr	ND
SACR-3	0.20	0.11	0.05	53.44	1.79	ND	tr	ND
SACR-4	1.31	0.45	0.07	53.38	0.93	ND	tr	ND
SACR-5	0.20	0.10	0.04	54.58	0.88	ND	tr	ND
SACR-6	0.29	0.17	0.06	54.50	0.93	ND	tr	ND
SACR-7	0.23	0.14	0.05	54.51	0.93	ND	tr	ND

ND = not done

CH and CG samples collected by Earl W. Hart and analyzed by Matti Tavala and Lydia Lofgren of California Division of Mines and Geology, 1963.

SACR-1 to 7 collected by Oliver F. Bowen of California Division of Mines and Geology and analyzed by Abbot A. Hanks, Inc., 1955.

CH-1 and 2 from quarry near W $\frac{1}{4}$ cor. 11-11S-2W, Cowell Home Ranch deposit A.

CH-3 and 4 and SACR-1 to 3 from quarry in SE $\frac{1}{4}$ 3-11S-2W, Cowell Home Ranch deposit B.

CG-1 and 2 from Cowell Home Ranch deposit F where crossed by Empire Grade—NW $\frac{1}{4}$ 10-11S-2W and SW $\frac{1}{4}$ 3-11S-2W, respectively.

SACR-4 is float from quarry at Holmes deposit, NE $\frac{1}{4}$ 20-10S-2W.

SACR-5 to 7 from quarry at IXL deposit, SE $\frac{1}{4}$ 17-10S-2W.

The Wilder Creek-Cave Gulch deposit has been developed only in sec. 9, where Henry Cowell Lime and Cement Company produced limestone for lime from about 1880 until the turn of the century. Limestone was worked in three quarries, the largest and most easterly being 300 feet in diameter and having a maximum face of nearly 100 feet. Two smaller quarries are situated to the west. Several hundred thousand tons of limestone were produced and burned at the nearby kilns, remnants of which still stand. The kilns were oil-fired and when it became uneconomic to haul oil to the kilns the operation was shut down.

Reserves. Limestone reserves of the Cowell Home Ranch deposits are difficult to estimate accurately because of poor exposures (soil cover, dense vegetation). However, based on an areal extent of about 250 acres of limestone outcrop (figure 4), combined limestone reserves may be estimated at 850,000 tons per foot of depth. This figure is too large in that it disregards limestone quality and includes noncarbonate rocks associated with the limestone. On the other hand, some of the limestone deposits may extend under soil overburden beyond the deposit limits mapped. It is clear that further exploration is necessary to assess the reserves of the various deposits. From an economic viewpoint, some of the advantages of the Cowell Home Ranch deposits are: 1) large reserves, 2) good accessibility, and 3) proximity to markets and major transportation lines. The main disadvantage is that much of the limestone lies on the campus of the University of California at Santa Cruz, construction of which began about 1964, and may not be available for future development. Beyond the campus boundary (figure 4), only the Wilder Creek-Cave Gulch deposit (F) appears to be of sufficient size to support large-scale development, but very little is known about specific reserves and limestone quality of that deposit. Deposits C, D, and E also lie partly outside the campus site and may be of future interest.

Other references: Brawne, 1868, p. 244; Ireland, 1888, p. 554; Crawford, 1896, p. 631; Aubury, 1906, p. 83; Laizure, 1926, p. 84; Hubbard, 1943, p. 43; Leo, 1967, p. 31, 41.

Holmes deposits. Location: NE $\frac{1}{4}$ sec. 20, T. 10 S., R. 2 W., M.D., 1 $\frac{1}{2}$ miles west of Felton; Ben Lomond 15-minute quadrangle. Ownership: Citizens Utilities Company of California, Boulder Creek, leased by Limestone Products, Incorporated (1963).

W. T. Holmes Lime Company produced large amounts of limestone for lime from these deposits for more than 52 years prior to 1936, when their operations ceased (Logan, 1947, p. 319). Production during the early years amounted to 50,000 to 100,000 barrels of lime per year (equal to about 10,000 to 20,000 tons of limestone per year) but was less later on. The limestone was burned in a series of pot and continuous kilns located between the deposits and Felton. Since early 1955, tailings at the main quarry have been

worked intermittently, and small amounts of limestone have been produced for use as road material and as roofing granules. Most or all of the later production was by Western Limestone Company (operated and owned in 1963 by Harry Crowley, Felton) apparently under a sublease arrangement with Limestone Products, Incorporated (a subsidiary of Granite Rock Company, Watsonville). The latest production was in late 1962 or early 1963, but the operator was preparing to produce additional limestone from existing tailings piles in August 1963 when the property was visited.

The Holmes deposits consist of massive beds of crystalline limestone and common schist interbeds exposed in several ill-defined areas in NE $\frac{1}{4}$ sec. 20. The largest deposit, lying astride Bennett Creek, covers an area perhaps 1,500 feet long east-west by 700 feet wide. Although much of the deposit is covered by quarry debris and vegetation, the limestone apparently occurs in crudely bedded sequences which are as much as 50 or 100 feet thick and which are interspersed at irregular intervals with thinner sequences of mica schist. Based on obscure stratification, the predominant dip appears to be about 50° N. The limestone is nearly white to gray, fine to coarse crystalline, and high in calcium. An analysis (SACR-4) of typical coarse-crystalline rock from the quarry is given in table 9. A few hundred feet south of the main area, near the crest of the ridge, a small deposit of similar limestone appears to dip about 60° S. To the east of this deposit are large tailings dumps consisting largely of off-white to gray, medium- to coarse-crystalline limestone. Other small limestone deposits are reported to the south and west (?) in NE $\frac{1}{4}$ sec. 20 but were not examined.

Development of the main Holmes deposits has been by surface and underground methods. The main quarry, consisting of several benches over a relief of about 400 feet, covers an area of 8 or 9 acres. At an elevation of about 1,250 feet just north of Bennett Creek, an adit leads to a series of underground rooms, supported by pillars and extending more than 400 feet to the west. Although the adit is partly caved at its portal, the workings are reported to be accessible and in good condition. At the southwest part of the deposit, a quarry with a floor elevation of 1,400 feet opens into the main quarry area. This quarry is about 150 feet wide, 400 feet deep, and has a maximum face of nearly 200 feet. Three hundred feet to the southeast, a smaller limestone deposit is developed by a quarry having a diameter of about 100 feet and a face of more than 100 feet. An old trainway site and a large tailings dump of medium- to coarse-crystalline limestone lie to the east of the quarry. Another old quarry is reported to the southeast near a southwest branch of Bull Creek. Remnants of two kiln sites can still be observed in sec. 21 immediately east of the deposits.

The present operator, Harry Crowley, has not done any quarrying but has utilized the extensive dumps at the main quarry as a source of limestone. A mill, locat-

ed below the lowest two benches, consists of jaw and gyratory crushers, screens, and two large metal storage bins. A portable crusher and grizzly also were previously used to produce crushed limestone. In August 1963, the operation was inactive except for repair work on the mill.

Based on the size of workings, total limestone produced at the various Holmes deposits may have aggregated more than a million tons. Recent production of limestone from tailings probably amounted to a few thousand tons per year. Limestone reserves are virtually impossible to estimate, as quarry debris, soil, and vegetation conceal much of the limestone and related schist. However, reserves at the main deposit could amount to several million tons or more. The deposits to the south appear much smaller, although reserves are undetermined. Extensive surface and subsurface exploration, including drilling, are needed to evaluate the deposits.

Other references: Ireland, 1888, p. 554; Crawford, 1894, p. 395; Aubury, 1906, p. 85; Huguenin and Costello, 1920, p. 238; Laizure, 1926, p. 85; Hubbard, 1943, p. 44; Leo, 1967, p. 31.

Ice Cream Grade deposits. Location: SE $\frac{1}{4}$ sec. 13, T. 10 S., R. 3 W. and W $\frac{1}{4}$ sec. 18, T. 10 S., R. 2 W., M.D., $3\frac{1}{2}$ miles west of Felton; Ben Lomond 15-minute quadrangle. Ownership: Not determined (1963).

Several small limestone deposits are exposed along Ice Cream Grade road in the vicinity of Laguna Creek. The limestone is crystalline and forms well-defined massive beds interlayered with schist and quartzite. These small deposits are somewhat impure and appear to be of little or no economic interest.

Two old stone lime kilns, situated on the east bank of Laguna Creek just south of the Ice Cream Grade road, testify to early efforts to develop limestone in the vicinity. The kilns are identical; each measures 15 feet by 21 feet on the inside, and both are completely open at the top (no stack). No limestone quarry was identified in the area, and there is evidence that only a little lime was burned. A quarry location and the general distribution of limestone outcrops is indicated by Branner *et al.* (1909, map) and Leo (1967, p. 30).

IXL deposit. Location: SE $\frac{1}{4}$ sec. 17, T. 10 S., R. 2 W., M.D., $1\frac{1}{2}$ miles west-northwest of Felton; Ben Lomond 15-minute quadrangle. Ownership: H. S. Cowell Foundation, 25 California Street, San Francisco (1963).*

A substantial amount of limestone for lime was produced from this deposit between the 1880s and 1919. The IXL Lime Company opened the deposit about 1885 or earlier and produced 50,000 barrels of lime per year (Ireland, 1888, p. 555; Crawford, 1894, p. 395). Around 1895, the deposit was being operated by Blackman and Cerf who manufactured small quanti-

* The deposit reportedly was purchased by Granite Rock Company in 1970 as a source of riprap.

ties of lime (Crawford, 1896, p. 631). The Henry Cowell Lime and Cement Company acquired the property about 1905 and produced a large amount of lime rock until 1919, when they ceased operations. There has been no development since that time.

The deposit is situated at the east end of a high, east-plunging spur flanked by South Fall Creek and a northwest tributary. The limestone has been mapped as an irregular lensoid mass (in plan), having a length of nearly 2,000 feet and a maximum width of 900 feet, and is exposed over 700 feet of relief (Leo, 1967, and unpublished Stanford thesis). It consists of thick beds of high-calcium limestone interbedded in some places with biotite schist. Where bedding can be observed, the strike is usually west or north west; but the dips are variable to the north and south, indicating structural complications. At one place on the north side of the deposit some granitic rock is exposed, but its relationship to the limestone is not known. Most of the limestone near the east end of the deposit is white to light gray, coarse to extremely coarse crystalline, generally graphitic, and high in calcium. However, some is fine to medium crystalline, white to dark gray, and mottled or banded. Chemical analyses of three samples (SACR-5 to 7) given in table 9 show the type coarse-crystalline limestone to be of good quality.

The deposit was worked at the east and north sides through several quarries. One quarry, situated about 250 feet higher than the kilns on the north side of the deposit, has a high face and is 40 feet by 40 feet in floor plan. A double-track tramway served the quarry and kilns. Lower in elevation and to the southeast is another quarry with a face of perhaps 200 feet. Remnants of a bank of three stone kilns and several enormous piles of broken limestone exist below the quarries.

Proved limestone reserves cannot be determined without drilling, particularly as the ratio and relationship of noncarbonate rocks to limestone is not known in detail. However, available limestone reserves may amount to several million tons or more. If the chemical analyses are representative of a substantial volume of rock, the deposit might be a useful source of limestone for the manufacture of glass and lime, and for other industrial uses.

Other references: Aubury, 1906, p. 86; Huguenin and Costello, 1920, p. 238; Laizure, 1926, p. 85; Hubbard, 1943, p. 44; Lagan, 1947, p. 319; Leo, 1967, p. 31.

Pacific Limestone Products Company (Kalkar; De Dero; Thurber; Caplatzi; Miller) deposits. Location: SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 11 and adjacent part of sec. 14, T. 11 S., R. 2 W., M.D., just west of Spring Street in northwest Santa Cruz (city); Santa Cruz 7 $\frac{1}{2}$ -minute quadrangle. Ownership: Pacific Limestone Products Company (estate of Fred W. Johnson), 535 Spring Street, Santa Cruz (1967).

The deposits consist of crystalline limestone uncovered in two adjacent quarries. The north quarry was worked by Louis De Dero (pre-1894 to 1907) and

W.A. Caplatzi (1907 to 1922), who produced crushed rock, poultry feed, and agricultural limestone. The south quarry was developed as a source of crushed rock at least as early as 1894 by T.J. (or S.L.) Thurber and later (pre-1920), on a smaller scale, by W.E. Miller (Crawford, 1894, p. 395; 1896, p. 631, 632; Aubury, 1906, p. 88, 324; Huguenin and Costello, 1920, p. 237, 239; Laizure, 1926, p. 86-88). Pacific Limestone Products Company began operations in 1922 when they took over the north (Caplatzi) quarry, and expanded in 1927 when they acquired the south (Miller) quarry (Hubbard, 1943, p. 44-46). Livestock feed and poultry grits, marketed as the "Kalkar" brand, have been the principal products of the present operation.

The two quarries are situated 450 feet apart on a gentle soil-covered slope. The area of limestone uncovered is about 8 acres at the north quarry and 3 to 4 acres at the south quarry (figure 4). Extent of the deposits beyond the quarries is masked by soil at least 6 to 8 feet thick. The deposits mainly consist of massive beds of coarse- to exceedingly coarse-crystalline, off-white to blue-gray, relatively pure limestone interbedded with thin beds, bands and lenses of impure limestone and calc-silicate rocks. The south deposit is also cut by a granitic dike. The impure interbeds, which are white to dark gray and generally fine grained, are more prevalent at the north deposit. Contact metamorphism and introduction of mineralizing fluids have given rise to the formation of a wide variety of silicates, sulfides, and arsenides, including some rare minerals (Gross *et al.*, 1967; Leo, 1967, p. 41). As a result, the locality has become noted as an important site for mineral-collecting. Both deposits are somewhat crushed and broken by minor faults. Bedding attitudes are obscure but appear to be gentle and to the north in the north quarry. Limestone reserves are unknown because the vertical and lateral extent of the deposits have not been determined. Chemical analyses of five samples (Kal-1 to 5) reflect the variable quality of limestone at the deposits (see table 10).

The two quarries have been worked on a modest scale for 70 years (prior to examination in 1963). The north quarry is the largest, having an irregular plan and maximum dimensions of 1,000 feet by 600 feet by 80 feet. Maximum dimensions of the south quarry are estimated to be 500 feet by 250 feet by 80 feet. Roughly 1 million tons of limestone and associated rocks have been quarried from the deposits. Both quarries are worked by primary and secondary blasting and hand-sorting. The impure limestone and calc-silicate rocks are stored in unused parts of the quarries for eventual sale as rubble and riprap. The purer coarse-crystalline limestone is hand-loaded into small skips, which are periodically picked up by special vehicles and delivered to the adjacent mill for processing. At the mill, which has a capacity of 100 tons per 8-hour day, the limestone is reduced in size through jaw and gyratory crushers, a hammer mill, and an impactor. The material is screened to several grit sizes and some is ground to flour. Poultry feed and grit are the most

Table 10. Chemical analyses of selected limestone samples, Pacific Limestone Products Company deposits, Santa Cruz County.

Description	Sample	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	P ₂ O ₅	Ignition loss	Total
South quarry (N¹/₄ cor. sec. 14-11S-2W)									
Coarse-crystalline, blue-gray limestone with small lensoid patches of fine-grained material.	Kal-1	2.90%	0.23%	0.12%	49.4%	1.00%	1.00%	41.0%	95.65%
White, coarse-crystalline limestone with 50% bands of fine-grained, quartzose limestone.	Kal-2	14.50	2.30	0.20	44.9	0.40	0.01	37.9	100.21
North quarry (SW¹/₄ sec. 11-11S-2W)									
Extremely coarse-crystalline, dove-gray to blue-gray limestone.	Kal-3	1.70	0.20	0.06	53.8	0.70	0.01	42.8	99.27
Same as Kal-3, but nearly white and with lenses of medium-grained quartz "sand".	Kal-4	19.50	1.20	0.50	41.5	0.50	0.01	36.7	99.91
Fine- to coarse-crystalline, light- to dark-gray, impure limestone.	Kal-5	6.10	1.60	0.30	38.7	12.90	0.34	39.5	99.44

Samples collected by E. W. Hart and analyzed by Matti Tavela, Division of Mines and Geology, 1963

important products, the various sizes being referred to as "flour, bird, fine, pidgeon, medium, coarse and turkey." The processed limestone is guaranteed by the operator to contain a minimum of 90% calcium carbonate. Additives—including phosphate, iron oxide, salt, copper, cobalt, zinc and sulfate—are blended with some of the products. The material is sold in bulk and in bags. In addition to the above products, rubble, riprap, and some agricultural limestone are sold. Shipments are made by truck or rail, principally to central California markets.

Other references: Fitch, 1931, p. 8; Logon, 1947, p. 320; Leo, 1967, p. 31, 41.

Peasley Gulch deposit. Location: SW¹/₄ sec. 9, T. 11 S., R. 2 W., M.D. (proj.), 3 miles west-northwest of Santa Cruz business district; Santa Cruz 7¹/₂-minute quadrangle. Ownership: Not determined.

A small body of crystalline limestone associated with schist and granodiorite is exposed in Peasley Gulch 1¹/₄ miles north of State Highway 1. The limestone exposures, which extend several hundred feet west of the gulch, cover a lenticular area about 400 feet long by 50 feet wide (Oliver E. Bowen, oral communication, 1965). Most of the limestone is off-white, coarse crystalline and high in calcium, although a thin zone of gray, medium-crystalline dolomite is present near the south contact. Typical limestone and dolomite samples, collected by Oliver E. Bowen, were analyzed by Lydia Lofgren of the Division of Mines and Geology in 1962:

Dts No.	CaO	MgO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	P ₂ O ₅	Ign. loss
44-PE-1	55.25%	00.51%	0.53%	0.09%	0.09%	0.0100%	43.49%
44-PE-2	33.20	19.09	1.24	0.25	0.25	0.0111	45.74

The deposit is not developed and probably is too small to be of economic interest.

San Vicente Creek deposit (Pacific Cement and Aggregates; Santa Cruz Lime Company; Santa Cruz Portland Cement Company). Location: Sec. 22, T. 10 S., R. 3 W., M.D., 2¹/₂ miles north-northeast of the PCA cement plant and the adjacent town of Davenport; Ben Lomond 15-minute quadrangle. Ownership: Pacific Cement and Aggregates Division, Lone Star Cement Corporation, 400 Alabama Street, San Francisco (1968).

The San Vicente Creek deposit was first developed about 1900 by the Santa Cruz Lime Company, which operated there for 5 or 6 years. They quarried limestone on the west side of San Vicente Creek and burned the material in three pot kilns, producing about 300 barrels of lime per day (Aubury, 1906, p. 87). In 1907, a cement plant was completed by Santa Cruz Portland Cement Company at Davenport, and the deposit has served as the source of cement rock ever since. The company merged with Pacific Coast Aggregate Company in 1956, the new firm emerging as Pacific Cement and Aggregates, Incorporated (Bowen and Gray, 1962, pt. 2, p. 4). About 1966, the company became a division of Lone Star Cement Corporation.

The deposit is situated astride San Vicente Creek where crystalline limestone is exposed in the quarry-expanded canyon for a length of 3,000 feet, a maximum width of 1,400 feet, and a relief of about 450 feet. Schist is locally interbedded with the limestone and constitutes part of the north, west, and south boundaries of the deposit. The limestone and schist are part of a metamorphic sequence of rocks considered to be equivalent to the Sur Series of pre-Cretaceous age. The metamorphic rocks were intruded by Cretaceous(?) quartz diorite, whose contact with the limestone is exposed along the northwest and southeast margins of the deposit (Branner *et al.*, 1909). Diorite is reported to penetrate the limestone body locally as

sills (Fitch, 1931, p. 3). Overlying the crystalline rocks on both sides of San Vicente Creek canyon and concealing the southwest and northeast extent of the limestone is a sequence of Miocene sedimentary rocks that dips gently southwest. A maximum thickness of 350 feet of sedimentary overburden is exposed west of the canyon and somewhat less is exposed to the northeast. From bottom to top, the sedimentary strata are composed of the following units, with estimated maximum thicknesses indicated: 1) hard calcareous sandstone of the Vaqueros Formation (?), 20–100 feet; 2) transitional softer concretionary sandstone, 100 feet; and 3) shale or mudstone of the Monterey Formation (?), 150 feet.

The attitude and subsurface extent of the limestone body is known only in places. Based on limited bedding features and the fact that schist was encountered in underground workings at a shallow depth below limestone exposed in the west wall of the canyon, the deposit appears to dip moderately northeast. If so, the main limestone reserves would lie east of the canyon beneath the sedimentary overburden. However, the projected distribution of the deposit at depth may be complicated by faulting as indicated by the broken and crushed nature of the limestone and the presence of minor faults.

Most of the limestone is off white to light blue gray, medium to very coarse crystalline, high in calcium, and locally graphitic. Some magnesia is locally present as silicates and dolomite but is considered a problem only at the north end of the deposit. Limestone and associated rocks (weathered schist and calc-silicate rocks) are commonly broken and crushed, the intermingling making it difficult to maintain good-quality limestone in some parts of the quarry. Clay and other noncarbonate fines tend to fill the interfragmental spaces, thereby further diluting the limestone. Disseminated pyrite is a common minor constituent in some parts of the deposit. An average analysis of the quarry-run limestone delivered to the mill is reported by the company (R. A. Kinzie, Jr., written communication, 1963) to be 43.6% CaO, 1.4% MgO, 14.5% SiO₂, 3.6% Al₂O₃, 1.5% Fe₂O₃, 0.6% SO₃, and 34.0% ignition loss.

Development of the deposit has been mainly southwest of San Vicente Creek, although the northeast wall of the canyon was worked to some extent in the early years. By 1963, the quarry had been expanded to an estimated maximum size of 2,700 feet by 1,600 feet. Quarry operations are carried out in three more or less distinct phases—stripping, quarrying, and underground transfer. Stripping of the sedimentary overburden is done periodically under contract, the last contract being completed in January 1963. The stripping bench uncovers a 150-foot-wide upper surface of limestone at an average elevation of 870 feet; and the sequence of sedimentary rock, 130 feet to more than 300 feet thick, is exposed in the bench face. Most of the overburden is wasted, except for the hard sandstone of

the Vaqueros Formation (?) which is utilized extensively as riprap and breakwater stone. Recent stripping should provide several years of limestone reserves before further stripping is necessary. Diamond drilling currently being conducted on the opposite side of the canyon is designed to develop limestone reserves in the northeast part of the deposit.

Quarrying is conducted along the southwest canyon wall where the developed limestone face rises 320 feet above the 550-foot elevation of the quarry floor. The limestone is worked through several shallow benches by blasting and bulldozing, the benches progressing down the face. Some selective quarrying is necessary to maintain desirable grades of limestone. Where schist is too prevalent, the material is wasted. Broken rock collected at the toe of the face is moved to glory holes on the quarry floor by end-dump trucks, which are loaded by power shovel, and by a Michigan loader.

The limestone is drawn through an underground transfer system which consists of three glory holes, each connected to main haulage ways by a transfer raise, bulldozing chamber, and loading chutes. Secondary blasting is used to reduce oversize blocks in the bulldozing chambers and “hang-ups” in the transfer system. The extensive underground transfer system has been changed little since its installation in 1924, although fewer glory holes are now employed. The system is described in detail by Young (1925, p. 249; 1929, p. 954). Open rail cars are filled at loading chutes in the haulage ways and transported by battery-powered locomotives to the mine opening. Electrically driven locomotives complete the 3-mile haul to the plant near Davenport.

At the plant, the material is reduced in gyratory crushers and stored by grade. Two grades of raw limestone are produced, based on the amount of contained alkalis and other impurities. Raw limestone from the storage piles is further processed by crushing, grinding, and blending with shale and roasted pyrite (“iron cinder”). The raw mix is then made into cement by the dry process, partly by the Lepol system and partly by conventional rotary kilns. The Lepol system consists of three kilns, each with four parts: 1) a drum-pelletizer where ½- to ¾-inch pellets are formed from the dry mix and added water; 2) a 47-foot traveling grate where the pellets are partially calcined; 3) a rotary kiln in which calcining of the pellets is completed; and 4) a moving-grate cooler. In addition to the Lepol system, some cement is produced from the dry mix in six rotary kilns in which conventional clinker is made.* A seventh kiln is used to calcine shale for the production of high-silica cement.

Much of the alumina and silica used for cement manufacture is derived from “shale” or mudstone of

* It is reported by the company (Herb Gaskin, 1971, personal communication) that the rotary kilns will be shut down by the end of 1971 because of stringent air-pollution control standards recently established by the State. The Lepol kilns currently (June 1971) produce a major portion of the total cement produced at the plant.

the extensive Monterey Formation (?). The mudstone is obtained by the operator from a hillside quarry located a mile northeast of the plant, near NW $\frac{1}{4}$ cor. sec. 34, and is shipped to the plant by rail. The material quarried is brownish gray, buff weathering, nonfissile, brittle, siliceous, and probably tuffaceous. Typical analyses of the mudstone, furnished by the company in 1961, ran as follows: 73–81% SiO₂, 7.5–11.0% Al₂O₃, 1.75–2.25% Fe₂O₃, 0.8–1.0% CaO, 0.4–0.6% MgO, 0.8–1.1% K₂O, and 0.3–0.6% Na₂O.

Annual rated capacity of the plant is 3 million barrels of cement. Yearly production is reported by Bowen and Gray (1962, plate 2, p. 4) to be roughly 840,000 tons of limestone and associated noncarbonate rock and 85,000 tons of mudstone (shale). Total production of limestone from the San Vicente Creek deposit is estimated to be about 25 million tons since 1907.

Pacific Cement and Aggregates Division owns another limestone deposit near Bonnie Doon. They recently drilled this deposit to determine its potential as an additional source of cement raw material (see Bonnie Doon deposit).†

Other references: Huguenin and Costello, 1920, p. 233, 239; Laizure, 1926, p. 75–78; Hubbord, 1943, p. 37–39; Logon, 1947, p. 320–321; Leo, 1967, p. 30; Clark, 1970.

Smith Grade deposit. Location: E $\frac{1}{2}$ sec. 25, T. 10 S., R. 3 W., M.D., 7 $\frac{1}{2}$ miles northwest of Santa Cruz; Felton 15-minute quadrangle. Ownership: Not determined (1963).

Crystalline limestone exposures along Smith Grade Road and Reggiardo Creek have been mapped as a relatively large deposit by Branner *et al.* (1909, map),

Leo (1967, p. 31; and unpublished Stanford thesis), and Clark (1970). The limestone commonly is coarse crystalline and high in calcium, but locally it is impure. Calc-silicate rocks, containing as much as 60% wollastonite, are exposed along the road, 1,000 feet west of the E $\frac{1}{4}$ cor. sec. 25; other silicate minerals are reported elsewhere in the limestone deposit. Quartzite and schist are locally exposed around the borders of the limestone and probably also exist as interbeds. Granitic dikes west of the creek further reduce the purity of the deposit.

As of August 1963, there was no known development. The deposit appears to be of only minor economic interest because substantial reserves of good quality limestone are not evident.

Wagner's Park deposit. Location: Probably 1 mile north of Santa Cruz business district; Santa Cruz 7 $\frac{1}{2}$ -minute quadrangle. Ownership: Not determined.

"Soft limestone" or "calcareous tufa" from a small gulch, at a place known as Wagner's Park, and clay from a nearby bluff were used experimentally by California Portland Cement Company (not the same as the firm currently operating in southern California) to produce portland cement around 1877. The combined materials were processed in a reverberatory furnace and kiln. Some cement was produced, but little or none was sold. The lack of success is reported to be due to litigation (Williams, 1883, p. 464) and competition from imported cement (Crawford, 1894, p. 380).

Chemical analyses (Irelan, 1888, p. 881) show two samples of limestone to contain 50.31% and 50.02% CaO, 2.40% and 4.71% SiO₂, and 1.45% and 1.80% alkalis. Irelan also presents chemical and physical data for cement, as well as chemical analyses for the clay and shale raw materials.

Other references: Williams, 1885, p. 676; Aubury, 1906, p. 184; Bowen and Gray, 1962, pt. 1, p. 6.

† Quarrying at the San Vicente Creek deposit ceased in mid-1970 concurrent with the opening of the Bonnie Doon deposit 2 miles to the southeast (see footnote under Bonnie Doon deposit). The San Vicente Creek deposit will be held as an emergency reserve. A major reason for its closing is believed to have been the cost of removing increasing amounts of overburden.

SOUTHERN COAST RANGES REGION (C)

The southern Coast Ranges region includes the Coast Ranges south of Monterey Bay and the Santa Ynez Mountains of the Transverse Ranges. The deposits lie in Fresno, Monterey, San Benito, San Luis Obispo, Santa Barbara, and Ventura Counties. The crystalline limestone and dolomite deposits in the Frazier Mountain area, at the southeast end of the Coast Ranges, and the various deposits of the Transverse Ranges east of the Santa Ynez Mountains were not part of this study and are not described herein.

Topographically, the southern Coast Ranges consist of a series of northwest-trending mountain ranges and intervening valleys that separate the broad San Joaquin Valley from the Pacific Ocean. Included among the principal mountain chains are all or portions of the Santa Lucia, Gabilan, Diablo, Temblor, and La Panza Ranges, and the San Rafael Mountains (plate 1C). At its southeast end, the Coast Ranges swing eastward, merging with the Santa Ynez Mountains and other east-trending Transverse Ranges.

The region is moderately populated, with most of the people residing in the Salinas-Monterey, Santa Barbara-Ventura, and San Luis Obispo-Santa Maria areas. The economy is based largely on agriculture, petroleum, and mining. As the region is quite mountainous, many of the carbonate deposits are of limited accessibility. Principal transportation routes are confined to the larger valleys and the less rugged coastal areas, and few paved roads cross the mountain ranges. The Southern Pacific Railroad connects the main cities with Los Angeles to the southeast (via the coast) and with San Francisco to the northwest (via Salinas Valley). There are no major deep-water ports in the region, although limited facilities are available at several ports between Monterey Bay and Ventura.

Historically, many deposits have been developed in the southern Coast Ranges region. Beginning in the 1880s, perhaps 20 limestone deposits were developed as sources of lime—mainly for local use although some limestone was shipped elsewhere in the region. Limestone for cement manufacture has been quarried since 1918 by Ideal Cement Company and its predecessors. Raw and calcined dolomite has been quarried continu-

ously since 1900 for refractory, chemical, and crushed rock uses, as well as for the manufacture of magnesium metal during World War II. Limestone, dolomite, and mixed carbonate rocks also have been used extensively for crushed rock, agricultural, and decorative purposes.

Between 1966 and 1968, the active dolomite deposits were the Natividad (Kaiser Aluminum and Chemical Corp.) and Westvaco (FMC Corp.) deposits of the northern Gabilan Range and the Missile City deposit in the western Santa Ynez Mountains. During that same period, limestone was quarried for cement manufacture at the Bryan and Pearce-Twohy deposit (Ideal Cement Company) in the Gabilan Range and for beet-sugar refining at Lime Mountain (Eaton and Smith) in the southern Santa Lucia Range. Total limestone and dolomite produced in 1968 amounted to about 907,000 tons.

The southern Coast Ranges region contains the largest reserves of limestone and dolomite of the Coast Ranges province. The principal deposits consist of crystalline limestone and dolomite of the metamorphosed Sur Series (pre-Cretaceous), fossiliferous and bioclastic limestone of the Sierra Blanca Limestone (Eocene) and Vaqueros Formation (lower Miocene), and impure fine-grained dolomite of the Monterey Formation (Miocene). Smaller or less pure carbonate deposits consist of dense limestone with chert, shell beds, veins, marl, marble onyx travertine, and possibly caliche that were formed from late Mesozoic(?) to Quaternary time.

In addition to the recently active deposits, the largest limestone deposits include the Pico Blanco deposit of the northern Santa Lucia Range and the Sierra Blanca deposit of the Santa Ynez Range. The lack of development at both of these deposits has been due to poor accessibility and, more recently, to the attention paid to the high recreational or wilderness values in these areas. An abundance of good quality limestone appears to be available at these deposits. Smaller deposits of limestone and dolomite of potential value exist in the Gabilan Range, northern and southern Santa Lucia Range, La Panza Range, and Santa Ynez Range. Carbonate deposits elsewhere in the region

appear to be of little economic interest because of size, impurities, or poor accessibility.

The limestone and dolomite deposits are discussed alphabetically below by districts (plate 1C). The districts, which are discussed from north to south, are the Gabilan Range, Panoche Hills, Northern Santa Lucia Range, Parkfield-Coalinga, Southern Santa Lucia Range, and Santa Ynez.

GABILAN RANGE DISTRICT (C-1)

The Gabilan Range district is a 10-mile-wide mountainous area that straddles the Monterey-San Benito County boundary between the Salinas Valley on the southwest and the San Andreas fault zone on the northeast. It extends 45 miles southeastward from U.S. Highway 101 to Topo Valley where it loses altitude and gives way to the so-called Gabilan Mesa. Although the Gabilan Range has a maximum elevation of only 3,454 feet at Mt. Johnson, much of it is deeply eroded and rugged and accessibility is somewhat limited. Rail facilities are available to the north at Hollister and San Juan Bautista and to the southwest at various points in the Salinas Valley. Limited port facilities exist at Moss Landing on Monterey Bay (plate 1C).

Pre-Tertiary crystalline rocks comprise the great bulk of the Gabilan Range. The oldest rocks are schist, gneiss, marble (limestone and dolomite), and quartzite of the Sur Series of pre-Cretaceous age. During Cretaceous(?) time, the Sur Series was extensively invaded by granitic intrusives, and only scattered roof pendants of the former remain—mainly in the northern half of the range. The granitic rocks range in composition from granite to quartz diorite but are mainly quartz monzonite and granodiorite. Overlying the crystalline rocks at the northern end of the range is a highly faulted and folded sequence of sedimentary and volcanic rocks of Oligocene to middle(?) Miocene age. Included in this sequence are thick red beds, breccias, and conglomerates of the Vaqueros Formation (lower Miocene) derived from the crystalline rock complex (Allen, 1946). The southeast end of the Gabilan Range is overlain by rhyolite flows and pyroclastics of Miocene age and various marine and non-marine sedimentary units of Miocene age and younger.

Limestone and dolomite deposits of economic interest are, with only one exception, restricted to pendants of the Sur Series. The exception is the Vaqueros Formation which contains thick red beds composed largely of crystalline limestone rubble derived from the Sur Series (see Barbee Ranch deposits). The general distribution of carbonate rock is fairly well known, although the extent and quality of many of the deposits remain to be learned. As can be seen in plate 2, many of the carbonate pendants form linear groups or belts that trend due west or northwest. Other trends also exist, suggesting a complex history of faulting and folding for the region.

The numerous carbonate bodies of the northern Gabilan Range consist of limestone, dolomite, and, more commonly, mixtures of limestone and dolomite (plate 2). Limestone tends to be more varied in its characteristics than dolomite, ranging from fine to exceedingly coarse crystalline and white to light and dark shades of blue gray. The dolomite is generally medium to coarse crystalline and white, cream or light blue gray. Both types of rock occur in pure masses, although dolomite often appears as replacement patches or bands in limestone. In many cases, carbonate rock is penetrated by dikes and fingers of granitic rock or is interleaved with schist and gneiss. Other deleterious materials associated with limestone and dolomite include quartz in the form of veinlets and replacement masses and silicate minerals developed in impure carbonate rock or adjacent to granitic contacts.

The largest reserves of limestone are available at the Bryan and Pearce-Twohy and the East Gabilan deposits, totaling an estimated 36 million tons. Ideal Cement Company controls both deposits, the former being worked until 1973 as a source of limestone for the company's cement plant at San Juan Bautista. Limestone reserves at the Upper Bird Creek, Blue Rock Mountain, Garner-Harris, and Palmtag-Harris deposits possibly amount to several million tons each. Other good-quality limestone deposits appear to be much smaller, but may be useful for special purposes. The Hamilton, A.S. and R., and Bardin Ranch deposits, for example, may be useful sources for whitening and white filler materials.

The Natividad and Westvaco deposits, both actively quarried as major sources of basic refractory raw materials, probably are the largest pure dolomite deposits in the Coast Ranges. Additional dolomite reserves are available at the Kaiser-Harris, Martin Ranch, McCray Ranch, and possibly the Porter Ranch deposits.

Large quantities of mixed carbonate rocks and impure limestone and dolomite exist in the Fremont Peak and Natividad areas. The development of these deposits, without the aid of beneficiation, appears to be limited to crushed rock uses. Some of the areas designated as "c" on plate 2 have not been examined carefully and may contain useful reserves of limestone or dolomite.

The various deposits of the Gabilan Range district are described alphabetically below.

A. S. and R. deposit. Location: W $\frac{1}{2}$ sec. 28 (proj.), T. 13 S., R. 5 E., M.D., 5 miles south of Hollister at the confluence of Bird Creek and North Canyon; Hollister 15-minute quadrangle. Ownership: Howard Harris, 7800 Cicnaga Road, Hollister (1959).

The deposit was held by American Smelting and Refining Company for many years prior to 1947, but it was never developed or even significantly prospected. The A. S. and R. deposit has been examined and described by Bowen and Gray (1959, p. 31) as follows:

"Pure white, and blue-gray and white variegated, coarsely crystalline limestone is in a thin, lenticular, vertical-standing pendant within granite and schist walls. It forms the crest of a ridge trending N 65°–70° W and has little or no overburden. The limestone is exposed for a length of 1,800 feet and on average width of 120 feet. A maximum of 200 feet of depth is exposed above the level of Bird Creek but the pendant continues downward for an undetermined distance. Accessible reserves in the lens probably exceed 1,000,000 tons. A few small granitic dikes penetrate the limestone but are not believed to be a serious problem in quarrying. Most of the limestone is white rather than colored. The following analyses on samples collected by the authors and analyzed by Abbot A. Honks, Incorporated, are believed to be representative of the variations found in the deposit."

Oxide	Sample G.P. 13	Sample G.P. 14	Sample G.P. 15	Sample G.P. 16
CaO	54.48%	50.79%	47.80%	52.24%
MgO	3.43	3.89	6.26	0.73
SiO ₂	1.74	0.36	0.58	3.66
Fe ₂ O ₃	0.19	0.17	0.17	0.23
Al ₂ O ₃	0.29	0.25	0.27	0.73
P ₂ O ₅	0.05	0.03	0.02	0.04

Recent investigations by Oliver E. Bowen, Thomas H. Rogers and Marshall E. Maddock (unpublished) indicate that the deposit is considerably smaller and contains substantially less limestone than the original estimate (Bowen, 1968, personal communication).

Considering the white color of most of the limestone, the deposit may have use as a source of whitening or for some other special purpose.

Barbee Ranch deposits. Location: SE $\frac{1}{4}$ sec. 9, T. 13 S., R. 4 E., M.D., 2 miles south of San Juan Bautista; San Juan Bautista 15-minute quadrangle. Ownership: Ideal Cement Company, 420 Ideal Cement Building, Denver, Colorado 80202 (1959).

Large blocks and boulders of crystalline limestone were quarried in a minor way many years ago in a few places in the vicinity of SE $\frac{1}{4}$ sec. 9 on the Barbee Ranch. Limestone detritus of the Sur Series constitutes a large percentage of reddish nonmarine breccias and conglomerates that occur as thick lenses in the Vaqueros Formation of early Miocene age. These lenses are interbedded with fossiliferous sandstone and constitute a unit as much as 1,000 feet thick. Concentrations of fragmental limestone extend westward for 5 miles between NW $\frac{1}{4}$ sec. 14, T. 13 S., R. 4 E., and N $\frac{1}{4}$ sec. 12, T. 13 S., R. 3 E. (Allen, 1946, p. 28–30). Three limestone samples collected and analyzed by the owner gave the following results (Bowen and Gray, 1959, p. 23):

Sample	CaO	MgO	Al ₂ O ₃	Fe ₂ O ₃	K ₂ O	Na ₂ O	SiO ₂
1	54.86%	0.43%	1.26%	0.46%	n.d.	n.d.	1.46%
2	54.86	0.52	0.89	0.33	n.d.	n.d.	1.06
3	51.02	0.57	1.73	0.75	0.06%	0.07%	5.10

Although limestone reserves may be large, expected variations in limestone composition and dilution with noncarbonate detritus may make this deposit unattractive as a future source of limestone.

Bardin Ranch deposits. Location: SE $\frac{1}{4}$ sec. 33 and SW $\frac{1}{4}$ sec. 34, T. 13 S., and NW $\frac{1}{4}$ sec. 3, T. 14 S., R. 4 E., M.D., 9 miles northeast of Salinas; San Juan Bautista 15-minute quadrangle. Ownership: Bardin Ranch, Salinas (1959).

Three patches of potentially commercial limestone, situated about a mile west of Fremont Peak, have been mapped by Bowen and Gray (1959, p. 28 and plate 1). These patches are parts of two larger carbonate masses of mixed limestone and dolomite of the Sur Series. Bowen and Gray briefly describe the patches:

"Part of the rock in these deposits is medium-grained, blue-gray material suitable for general use where color is not important, and part is coarse-grained, pure-white material suitable for whitening and white filler. None of the deposits has been developed or tested except for a few samples taken by the authors but, judging from surface exposures, more than a million tons of commercial material might reasonably be developed in the three masses. They are currently accessible by Gabilan Creek Canyon via an unimproved dirt road."

Bird Canyon Ledge. Location: SE $\frac{1}{4}$ sec. 31 (proj.), T. 13 S., R. 5 E., M.D., 7 miles southwest of Hollister; Hollister 15-minute quadrangle. Ownership: Ideal Cement Company, 420 Ideal Cement Building, Denver, Colorado 80202, holds the mineral rights (1959).

Old Mission Portland Cement Company, predecessor to the present owner, acquired and drilled the Bird Canyon Ledge in 1925 in order to increase their reserves of cement raw materials. The deposit has been mapped and described in some detail by Bowen and Gray (1959, p. 31–32, plate 1):

"The Bird Canyon Ledge occupies the south slope of a ridge trending N. 65° E. The north border of the principal limestone mass lies close to the ridge crest. The south border, which is more regular, lies close to the canyon bottom. In plan the deposit is about 600 feet long parallel to the ridge and 800 feet long perpendicular to the ridge. From ridge crest to creek bottom, a depth of 560 feet of limestone is exposed. The predominating surface trace of well-developed joints in the limestone strikes N 55°–60° E and the joint surfaces dip very steeply southeast, but it is doubtful if this represents bedding. Bonafide bedding was not observed in the main mass. The limestone is bounded on the north and south by quartzitic schist and granite; on the east by granite; and on the west by a mass of gray replacement silico. From exposures seen along the creek the deposit bottoms in granite and silico and the chances of it continuing down below the level of the creek bottom are small. Roughly 10,000,000 tons of carbonate rock are present in the main mass but there is some question as to whether all of this is suitable for manufacture of portland cement."

The analyses in table 11 indicate the deposit to be too high in magnesia for use in Portland cement. The deposit is undeveloped.

Bluerock Mountain deposit. Location: SW $\frac{1}{4}$ sec. 25 and SE $\frac{1}{4}$ sec. 26, T. 14 S., R. 4 E., M.D., 9 miles east of Salinas and nearly 8 miles north and slightly east of Chualar; Gonzales 15-minute quadrangle. Ownership: Not determined.

This deposit lies on the rugged west slopes of Bluerock Mountain. It is briefly described by Bowen and Gray (1959, p. 37) as "an oval mass having a slight east elongation and underlies most of the SW $\frac{1}{4}$ sec. 25 . . .

Table 11. Chemical analyses of samples from the Bird Canyon Ledge (after Bowen and Gray, 1959, p. 32).

Sample	CaO	MgO	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	P ₂ O ₅	N ₂ O	K ₂ O	Ignition loss (chiefly CO ₂)
G-21.....	51.20%	3.25%	7.36%	0.19%	0.39%	ND	0.14%	0.05%	37.88%
G-22.....	50.00	3.26	3.72	0.23	0.35	ND	0.09	0.03	42.21
G-23.....	35.60	17.54	9.96	0.73	0.89	ND	0.05	0.05	34.27
G-24.....	41.70	14.94	2.12	0.12	0.22	ND	0.03	0.01	39.68
G-25.....	39.00	19.13	4.86	0.39	0.51	ND	0.03	0.01	34.66
G-26.....	39.10	13.74	4.00	0.53	1.05	ND	0.05	0.10	39.68
G-42.....	53.93	1.21	0.80	0.05	0.20	0.03%	ND	ND	ND
G-43.....	54.83	0.80	0.10	0.05	0.02	0.27	ND	ND	ND
G-44.....	43.38	0.15	17.90	0.02	3.67	0.01	ND	ND	ND
G-45.....	46.17	7.84	0.81	0.03	0.21	0.01	ND	ND	ND
G-46.....	42.29	7.38	6.22	0.25	1.80	0.17	ND	ND	ND
G-47.....	36.86	13.95	3.72	0.13	0.70	0.10	ND	ND	ND
G-48.....	46.64	4.45	6.04	0.16	0.68	0.14	ND	ND	ND
G-49.....	44.74	6.79	4.24	0.14	1.16	0.56	ND	ND	ND
G-50.....	29.64	18.57	7.06	0.17	0.83	0.10	ND	ND	ND
G-51.....	34.63	17.54	0.12	0.03	0.03	0.02	ND	ND	ND
G-52.....	38.00	11.37	6.04	0.03	1.79	0.07	ND	ND	ND
G-53.....	50.95	1.91	3.52	0.02	0.42	0.16	ND	ND	ND
G-54.....	35.88	16.78	0.28	0.02	0.12	0.01	ND	ND	ND
G-55.....	49.45	5.34	0.32	0.01	0.07	0.03	ND	ND	ND

ND=Not done.

Samples G-21 through G-26 were analyzed by L. A. Caetano, Ideal Cement Company, San Juan Bautista. Samples G-42 through G-55 were analyzed by Abbot A. Hanks, Inc., San Francisco, 1958.

Most of the mass appears to be medium crystalline, blue-gray limestone. Reserves probably aggregate many millions of tons." Although the deposit is undeveloped, it appears worthy of some future sampling and exploration in order to assess the potential resources. It is accessible by dirt roads from the Salinas Valley.

Bryan and Pearce-Twohy (Ideal Cement Company) deposit. Location: N½ sec. 24 (proj.), T. 13 S., R. 4 E., M.D., 5 miles southeast of San Juan Bautista; Hollister 15-minute quadrangle. Ownership: Ideal Cement Company, 420 Ideal Cement Building, Denver, Colorado 80202, holds mineral rights (1963).

In 1927, Pacific Portland Cement Company (predecessor to present owner) acquired the holdings of Old Mission Portland Cement Company and intensively prospected this deposit by core drilling and surface sampling. Later (1941?), a quarry was developed to provide limestone for renewed cement manufacture. The plant was shut down between 1930 and 1941. The plant closed again in 1943 but reopened in early 1947. Shortly thereafter, the Bryan and Pearce-Twohy deposit became the principal source of limestone used at the cement plant near San Juan Bautista.*

The deposit consists of two adjacent masses of crystalline limestone associated with schist of the Sur Series and cut by intrusions of granitic rocks. An early map of the deposit (Pacific Portland Cement Company, 1927, unpublished) shows the largest mass to be northwest-trending and irregular in plan. It has a

length of 2,300 feet and an average width of about 400 feet and is exposed through at least 550 feet of relief. A smaller mass, roughly 600 by 500 feet in plan, is situated immediately west of the main mass. Limestone beds in the main mass generally dip 20° to 50° S, being steeper to the south, and probably represent 200 to 300 feet of stratigraphic thickness. Apparently the deposit is somewhat broken by faulting, as indicated by the presence of breccia and fault gouge in the quarries. The limestone is medium to coarsely crystalline, white to blue gray, and uniform in appearance and chemistry. The average analysis of 50 surface samples and 500 feet of diamond drill cores, sampled and analyzed by Ideal Cement Company, shows 51.1% CaO, 1.4% MgO, 41.7% CO₂, 4.1% SiO₂, and 1.7% Fe₂O₃ and Al₂O₃ (Bowen and Gray, 1959, p. 25). Based on the dimensions of the limestone masses, limestone reserves are estimated to be 8 to 9 million tons per hundred feet of depth. Granitic intrusives and other noncarbonate rock inclusions reduce reserve estimates significantly, but to an unknown extent. Bowen and Gray (1959, p. 25) estimate total reserves to be about 20 million tons; but, due to unfavorable stripping ratios, part of the limestone is not recoverable by surface methods.

Development of the deposit is centered in two quarry areas in the main limestone mass. According to Oliver E. Bowen (1963, personal communication), the largest quarry is situated along the crest of the main east-trending ridge. In 1961, it was reported to be about 1200 feet long by 200 to 300 feet wide. A smaller quarry to the southeast covered an area roughly 800 feet long (east-west) by 100 to 200 feet wide. The

* Quarry operations ceased about 1973 (see Ideal Cement Company—San Juan Bautista footnote on p. 63).

limestone is worked by benching at 30- to 50-foot intervals. After preliminary crushing and screening at the quarries, the limestone is trucked about 6 miles to the company plant (see Ideal Cement Company, San Juan Bautista plant). At one time rail facilities connected the plant with the deposit.

Buzzard's Roost deposit. Location: E½ sec. 14, T. 14 S., R. 5 E., M.D., 9½ miles south of Hollister; Gonzales 15-minute quadrangle. Ownership: S. H. Cowell Foundation, 2 Market Street, San Francisco, and possibly others (1962).

Bold, craggy outcrops of carbonate rock are exposed at and near the summit of a 2645-foot peak, locally known as Buzzard's Roost. The mass is not readily accessible and has not been examined but is reported to consist of crystalline limestone of the Sur Series. As viewed from the east, the limestone appears to extend to the north as a persistent ledge near the crest of a north-trending spur. The mass extends over a length of half a mile and apparently is gently dipping. A smaller lens of carbonate rock lies a few hundred feet southeast of the main mass on a spur of the peak. These bodies are shown as a single large mass by R. E. Dempster (unpublished mapping shown by Jennings and Strand, 1958). The deposit may contain several million tons or more of limestone and would certainly warrant close examination and sampling. It is most accessible from the south, lying about half a mile north of the dirt road to the Hamilton deposit.

Chalone Creek deposit. An undeveloped limestone deposit reportedly located 6 miles east of Metz in the southeast part of T. 17 S., R. 7 E. (Gonzales 15-minute quadrangle) in Monterey County is mentioned by Logan (1947, p. 259). The deposit was not located. However, several small, scattered bodies of Sur Series limestone are shown by Jennings and Strand (1958) to lie 5 to 9 miles north of Metz. These were not examined.

Cowell-Thompson Creek deposit. Location: N½ sec. 30, T. 14 S., R. 6 E., M.D., 11 miles south of Hollister; Gonzales 15-minute quadrangle. Ownership: S. H. Cowell Foundation, 25 California Street, San Francisco (1959).

This deposit, located on the north side of Thompson Creek, was developed in 1885 by J. J. Bart who calcined the limestone in two upright kilns (Irelan, 1888, p. 488). The property was also operated in the 1890s by Cienega Lime Company which operated four continuous kilns. No additional work has been done since the property was acquired by Cowell Lime and Cement Company about 1900.

The Thompson Creek deposit is reported by Bowen and Gray (1959, p. 37) to be a sheetlike mass that dips steeply north. It is exposed on steep terrain over a length of half a mile and a width of 60 to 100 feet. The limestone is white to blue gray, medium to coarse crystalline, and apparently low in impurities, al-

though no analyses are available. Granite dikes and schist interbeds exist at numerous places. Although this deposit may contain several million tons of limestone, only a small percentage of that could be obtained by surface quarrying because of the relation of the steep topography with the attitude of the thin lens. Selective mining probably would be necessary to maintain a uniform grade of rock.

Other references: Crawford, 1896, p. 629; Loizure, 1926, p. 237; Logan, 1947, p. 276.

Crowe Ranch deposits. Limestone and dolomite deposits, mentioned by Logan (1947, p. 274, 278) as part of the Cassie Crowe holdings east of Fremont Peak in San Benito County, are described herein as the A. S. and R., Bird Canyon Ledge, Garner-Harris, Harmony Hills, Kaiser-Harris, Middle Dam, and Palm-tag-Harris deposits.

East Gabilan deposit. Location: SW¼ sec. 36 (proj.), T. 13 S., R. 4 E., M.D., 1 mile east and slightly south of Fremont Peak and 7 miles southeast of San Juan Bautista; Hollister 15-minute quadrangle. Ownership: Rollin Reeves Ranch, Salinas (mineral rights leased to Ideal Cement Company, 1959).

According to Bowen and Gray (1959, p. 28, 30, plate 1), "the East Gabilan deposit is the largest in the Fremont Peak district and is situated on terrain favorable to low-cost quarrying." The deposit is a relatively pure limestone portion of a large body of mixed limestone and dolomite. Bowen and Gray further describe the deposit as follows:

"As seen in plan, the limestone mass overages about 300 feet in width and is approximately 2,800 feet long. The beds, though crudely defined, strike N. 70–80° W., and dip 65–80° N. Erosion has exposed limestone to a depth of 140 feet below the highest outcrops and the mass has been penetrated by several hundred feet of adits, driven for sampling purposes by predecessors to Ideal Cement Company. Although overlain stratigraphically by dolomite and dolomitic limestone, the stratigraphic sequence dips too steeply for such material to cause an overburden problem. Over most of the deposit there is no overburden whatever. Estimated reserves calculated to a depth of 240 feet below the uppermost outcrops (a reasonable recovery depth) total approximately 16,000,000 tons. Substantial additional tonnage could be developed by underground mining methods."

The analyses in table 12 are typical of the limestone.

Table 12. Chemical analyses of limestone from East Gabilan deposit, Monterey County (after Bowen and Gray, 1959, p. 31).

Oxide	#1	#2	#3	#4	#5	#6	#7
CaO	55.42%	54.42%	54.73%	54.43%	54.37%	54.35%	54.02%
MgO	0.41	0.92	0.41	0.53	0.45	0.48	0.99
SiO ₂	0.24	0.94	1.52	0.86	0.86	0.92	0.82
Fe ₂ O ₃	0.20	0.14	0.32	0.11	0.08	0.11	0.13
Al ₂ O ₃	0.10	0.14	0.34	0.29	0.26	0.17	0.13
K ₂ O	0.03	0.02	0.06	ND	ND	ND	ND
Na ₂ O	0.04	0.03	0.02	ND	ND	ND	ND
P ₂ O ₅	ND	ND	ND	0.06	0.03	0.02	0.02
Ignition loss (chiefly CO ₂) ..	43.72	43.53	43.18	ND	ND	ND	ND

ND = not done

Samples 1–3 were analyzed by Ideal Cement Co., samples 4–7, by Abbot A Hanks, Inc.

Flint-Steinbeck deposit. Location: S $\frac{1}{2}$ sec. 23, T. 13 S., R. 4 E., M.D., $\frac{4}{5}$ miles south-southeast of San Juan Bautista; San Juan Bautista and Hollister 15-minute quadrangles. Ownership: Ideal Cement Company, 420 Ideal Cement Building, Denver, Colorado 80202 (1959).

This deposit was a principal source of limestone used in cement manufacture near San Juan Bautista in the 1920s and 1940s. Limestone was produced from quarries on both sides of a north-trending ridge and transferred to the plant via a narrow gauge railroad. The deposit has not been worked in recent years. Since about 1950, the Bryan and Pearce-Twohy deposit, located $1\frac{1}{2}$ miles to the northeast, has been the major source of limestone used at the plant. Bowen and Gray (1959, p. 25) describe the deposit as follows:

"Limestone occurs in a long thin lens, set on edge, the edge trending N. 80° E. The sheetlike mass, tapered at both ends, dips steeply south, has a traceable length of nearly 3,000 feet and an average width of about 100 feet. It has been exposed to a maximum depth of 440 feet by erosion but probably continues below the level of the adjacent canyon-bottoms. Wall rocks are granite and quartz-mica schist. The limestone is similar in physical character and chemical content to the rock from the Bryan and Pearce-Twohy properties. Considerable limestone remains in the lens but recovery would be expensive because of the attitude of the mass and because of the steepness of the topography. Much of the remaining material would have to be mined underground or else stripped at high cost."

Other references: Loizure, 1926, p. 226; Logon 1947, p. 276.

Fremont Peak deposit. Location: S $\frac{1}{2}$ sec. 35 (proj.), T. 13 S., R. 4 E., M.D., about a quarter mile south and east of Fremont Peak and $\frac{6}{10}$ miles south-southeast of San Juan Bautista; San Juan Bautista and Hollister 15-minute quadrangles. Ownership: Reeves Ranch and Bardin Ranch (1959).

This deposit consists of four substantial masses of medium- to coarse-crystalline, pale blue-gray limestone grouped about the south flank of Fremont Peak. These masses have been mapped and briefly described by Bowen and Gray (1959, p. 31, plate 1), who estimate the probable total reserves to be a million tons. Three samples of representative limestone were analyzed by L. A. Caetano of Ideal Cement Company. The analyses are given below:

Oxide	Sample G-13	Sample G-14	Sample G-15
CaO	55.02%	53.94%	55.52%
MgO	0.69	1.53	0.46
SiO ₂	1.58	0.42	0.14
Al ₂ O ₃	0.58	0.08	0.17
Fe ₂ O ₃	0.30	0.08	0.13
K ₂ O	0.03	0.01	0.01
Na ₂ O	0.04	0.01	0.04
Ignition loss (chiefly CO ₂)	42.14	43.62	43.60

In addition to the main limestone deposits described above, small masses of relatively pure dolomite and limestone a short distance to the south and east have been mapped by Bowen and Gray, some of which may warrant future prospecting.

Garner-Harris deposits. Location: S $\frac{1}{2}$ sec. 34 (proj.), T. 13 S., R. 5 E., M.D., three quarters of a mile west of Vineyard School and 6 miles south of Hollister; Hollister 15-minute quadrangle. Ownership: Howard Harris, 7800 Cienega Road, Hollister, owns the old Garner property west of Bonanza Gulch (1962).

Several medium-sized to small masses of crystalline limestone lie on the north and east flanks of a 1,916-foot hill (see geologic map, plate 2). The limestone bodies, which are interbedded with schist and intruded by granitic rocks, generally trend west-northwest. The limestone is typically medium to coarse crystalline, blue gray to off white, and frequently banded, mottled, or brecciated. Some dolomite is present as thin bands of near-white, medium-crystalline rock in the limestone. Heavy soil, caliche, and vegetation effectively mask the extent of the deposits. However, prospecting has helped to define the deposit boundaries.

Development of the deposits has been limited to shallow prospect cuts and some stripping. A series of 137 samples, collected at regular intervals and analyzed by the owner, indicate the deposits to be of variable composition. Analyses, kindly furnished by the owner, are given in table 13. Possibly 3 or 4 million tons of limestone are present here, but much of this would have to be mined selectively due to local concentrations of dolomite and granitic impurities. From an economic viewpoint, the Garner-Harris deposits would appear to be useful mainly as a reserve source of cement raw material. Four of the larger deposits, examined in October 1962, are discussed below.

Big Flat deposit. This deposit is located in S $\frac{1}{2}$ SE $\frac{1}{4}$ sec. 34, 3,000 feet southwest of Vineyard School. It is pear-shaped in plan, with maximum dimensions of 800 feet by 500 feet and is exposed through 300 feet of relief. A thick surficial layer of caliche masks much of the lower part of the deposit, even where prospect cuts exist. Where exposed, the limestone is light to dark gray, medium crystalline, partly brecciated, and locally siliceous. Some white, iron-stained dolomite exists on the north side of the mass. In table 13 a series of samples (BFA, BFB, BFC, BFD), collected and analyzed by the owner, indicate the limestone to be low in MgO but to contain variable amounts of SiO₂, Al₂O₃, and Fe₂O₃. Samples BF 1-16 represent the chemical variations of the caliche. If the analyses are representative of the deposit as a whole, use of the limestone is probably limited to cement manufacture. Reserves of limestone, including impurities and granitic dikes, are estimated to be no more than 18,000 tons per foot of depth.

Dry Trough deposit. The deposit is located in SW $\frac{1}{4}$ sec. 34 (proj.), 4,500 feet west of Vineyard School. It trends N 70° W and consists of limestone and some dolomite exposed over an area having maximum dimensions of 1,300 feet by 400 feet with 250

feet of relief. Medium- crystalline, blue-gray, sometimes banded or variegated limestone is the chief rock type. White medium-crystalline dolomite exists in thin bands near the north and south margins of the mass. The limestone is farther from the San Andreas fault zone and is generally less brecciated than other deposits in the Garner-Harris group. Development is limited to several prospect cuts from which the owner has collected 20 samples for analysis (see DT and DT 2 series in table 13). With the exception of one dolomite sample (DT2 1), the analyses show an average of about 51% CaO and 4% SiO₂. Total carbonate rock reserves are estimated to be no more than 15,000 tons per foot of depth. Selective mining would be necessary to develop the deposit, and recoverable reserves may be less than indicated.

West Boundary deposit. A poorly exposed mass of limestone trending N 70° W is situated a few hundred feet northeast of the Dry Trough deposit. It extends over an area 1,700 feet long by a maximum of 250 feet wide. Smaller bodies of carbonate rock lie close by to the southwest and east. The limestone is mainly off white, medium to coarse crystalline, and partly brecciated. Although outcrops are scattered, prospect cuts and stripping partly define the mass. In recent years, Howard Harris has collected and analyzed 36 samples from this deposit (see samples of WB and G series, table 13). Chemical analyses indicate that the limestone contains variable amounts of silica and little magnesia (two exceptions). Total reserves appear to run about 12,500 tons or less per foot of depth.

Blue deposit. This small lenticular mass trends N 70° W and lies just east of the Dry Trough deposit. Maximum dimensions are about 700 feet by 125 feet. It consists of light-gray to blue-gray, medium-crystalline limestone containing some thin bands of white dolomite. Development is limited to several shallow prospect cuts from which 15 samples were obtained for analysis (B and BA series, table 13). Estimated reserves are less than 5,000 tons per foot of depth. Considering the variable chemical composition of the samples and apparent small reserves of limestone, the deposit would not appear to be of significant commercial value.

Reference: Bowen and Gray, 1959, p. 33.

Hamilton deposit. Location: N½ sec. 23, T. 14 S., R. 5 E., M.D., 10 miles south of Hollister; Gonzales 15-minute quadrangle. Ownership: Mrs. A. E. Hamilton, Cicnega Road, Hollister (1962).

This deposit includes three closely grouped lenses of limestone, each of which has been developed to some extent. There is some confusion in the literature regarding ownership, operations, and locations. Limestone property in sec. 23 has been owned at various times by U. G. Harlan; San Benito Lime Company (Connelly and Krusc); Archer Lime Company (D. McPhail); Hamilton, Fontaine, and Temple; W. R.

Fontaine; and Marie Mayries. From 1890 to about 1907, limestone was quarried and burned locally by U. G. Harlan and probably even earlier by San Benito Lime Company (Bradley and Logan, 1919, p. 340, 342; Averill, 1947, p. 51-52). The San Benito Lime Company deposit apparently was acquired about 1925 by Hamilton and associates and worked as a source of lime rock and agricultural limestone from 1930 to 1932. During the 1950s and early 1960s, A. E. Hamilton did considerable development work but was unable to realize commercial production in recent years. At the time of his death in 1962, a crushing-screening plant, located just east of the main lens, was well toward completion. A jaw crusher at the plant has a capacity of 200 tons per hour.

The Hamilton deposit is situated on a 2,831-foot hill just north of Harlan Creek. It consists of three elongate lenses extending half a mile north and slightly east of the center of sec. 13. Perhaps the largest lens occupies the north half of the deposit and is about 1,300 feet long by a maximum of 275 feet wide. A few hundred feet to the south are two adjacent, parallel lenses, each about 1,000 feet long by 100 to 150 feet wide. Smaller masses of carbonate rock exist to the east and west. The various lenses consist mainly of white, extremely coarse-crystalline limestone associated with white to cream, medium-crystalline dolomite, particularly near the margins. The country rock and the numerous dikes that cut the lenses are granodiorite, now decomposed.

The north lens trends north-northeast, is slightly arcuate in plan, and appears to dip steeply to the east. It is developed at its south end by a small quarry, a 275-foot tunnel, and prospect cuts near the summit of the hill. The limestone contains scattered graphite crystals and small amounts of white, finely fibrous tremolite asbestos distributed along shear planes. A typical sample of the coarse-crystalline limestone, containing minor graphite and tremolite, was analyzed by Lydia Lofgren in 1963. It contained 53.6% CaO, 1.53% MgO, 0.56% SiO₂, 0.06% Al₂O₃, 0.05% Fe₂O₃, 0.01% P₂O₅, and 43.62% ignition loss. The lenticular body is locally dolomitic at its northeast end and west margins. Estimated reserves of limestone are on the order of a million tons.

Two parallel lenses constitute the south half of the deposit. The east lens was developed by a small quarry near its north end. Here the limestone is white but locally discolored, and some dolomite is present along the west margin. The lens strikes N 10° E and dips about 60° E. In addition to the quarry, the body is developed by several prospect cuts.

Immediately to the west is a parallel, somewhat thinner lens that appears to have an average width of less than 100 feet. This body may be a detached extension of the main mass a few hundred feet to the north. In the quarry exposures at the south end of the lens, the limestone appears to dip steeply east and is truncated on the down-dip side by granitic rocks. The

Table 13. Chemical analyses of Garner-Harris deposits, San Benito County, by Howard Harris, owner.

Sample	SiO ₂	CaO	MgO	Al ₂ O ₃ .Fe ₂ O ₃	Sample	SiO ₂	CaO	MgO	Al ₂ O ₃ .Fe ₂ O ₃
BIG FLAT DEPOSIT					DT 4	4.0	51.89	0.31	0.5
BFA 1	5.00%	55.8 %	0.42%	1.40%	DT 5	2.9	51.92	0.44	1.7
BFA 2	6.40	50.5	0.42	1.40	DT 6	2.3	51.39	0.44	1.7
BFA 3	4.60	52.5	0.39	0.80	DT 7	3.0	50.83	0.19	1.8
BFA 4	3.80	52.3	0.39	1.00	DT 8	2.8	52.86	0.44	0.9
BFA 5	2.50	53.8	0.30	0.80	DT 9	3.0	50.31	0.41	1.8
BFA 6	2.60	53.70	0.30	1.00	DT 10	3.0	50.52	0.67	1.5
BFA 7	3.40	52.20	0.45	1.30	Top of ridge				
BFA 8	5.00	53.00	0.42	1.30	DT2 1	5.5	36.41	12.70	1.5
BFA 9	2.50	52.70	0.39	0.90	DT2 2	4.9	50.52	7.37	1.0
BFA 10	5.00	51.90	0.28	1.30	DT2 3	3.9	53.50	0.75	1.0
BFA 11	2.70	53.00	0.36	1.00	DT2 4	4.6	51.26	0.58	1.4
BFA 12	3.20	52.20	0.80	0.70	DT2 5	11.9	46.10	0.58	1.9
BFA 13	3.20	52.20	0.80	0.60	DT2 6	6.8	51.56	0.50	0.9
BFA 14	0.90	54.00	0.72	0.30	DT2 7	4.9	52.35	0.40	0.7
BFA 15	1.50	53.40	0.85	0.60	DT2 8	3.0	51.29	0.29	0.7
BFA 16	0.60	53.00	1.25	0.50	DT2 9	3.6	48.10	0.36	0.7
BFA 17	1.50	52.30	1.95	0.20	DT2 10	3.7	51.55	1.40	0.7
BFA 18	0.80	52.80	1.80	0.30	WEST BOUNDARY DEPOSIT				
BFA 19	0.80	52.20	2.20	0.15	G 1	18.80	42.50	0.28	2.00
BFB 1	3.30	52.70	0.70	0.80	G 2	4.90	51.50	0.72	1.50
BFB 2	3.10	52.50	1.08	0.80	G 3	17.80	43.40	0.28	2.20
BFB 3	9.70	48.30	0.65	1.70	G 4	5.10	51.90	0.28	1.00
BFB 4	4.80	51.40	0.70	1.50	G 5	3.90	52.90	0.36	0.90
BFB 5	33.30	32.90	1.25	3.90	G 6	0.50	34.00	18.65	0.40
BFB 6	36.30	27.90	0.95	7.30	G 7	0.70	53.70	1.37	0.50
BFB 7	37.40	28.70	0.90	4.40	G 8	1.50	54.30	0.61	0.50
BFB 8	7.90	49.10	0.90	1.70	G 9	4.20	52.70	0.32	0.70
BFB 9	20.10	42.10	0.07	2.30	GL 1	11.05	48.55	0.21	3.80
BFB 10	69.70	13.80	0.12	3.60	GL 2	4.25	53.60	0.36	1.35
BFB 11	84.60	2.40	0.11	8.10	GL 3	4.85	51.15	0.21	1.35
BFB 12	25.30	35.90	0.10	5.00	GL 4	3.15	53.30	0.18	1.40
BFB 13	5.70	50.40	0.09	1.90	WB 1	3.25	52.55	0.43	1.11
BFC 1	3.00	51.80	0.90	1.10	WB 2	2.20	54.00	0.37	0.92
BFC 2	1.20	54.00	0.90	0.70	WB 3	2.75	55.00	0.01	0.58
BFC 3	2.20	52.50	1.15	0.90	WB 4	4.30	53.80	0.08	0.79
BFC 4	3.40	52.50	0.60	1.10	WB 5	5.75	52.10	0.28	1.39
BFC 5	3.20	51.40	0.60	0.90	WB 6	15.50	44.64	0.009	2.26
BFD 1	1.20	53.60	0.90	0.50	WB 7	30.67	37.30	0.21	1.16
BFD 2	2.40	52.60	0.60	1.30	WB 8	9.24	49.20	0.32	0.96
BFD 3	2.60	52.80	0.30	1.00	WB 9	7.42	45.45	5.40	0.96
BFD 4	3.80	52.90	0.30	1.20	WBT 1	1.70	54.20	0.90	0.40
BFD 5	4.50	50.50	0.30	1.30	WBT 2	1.00	55.60	0.86	0.20
BFD 6	3.20	51.25	0.15	0.80	WBT 3	1.10	54.40	1.58	0.20
BFD 7	2.90	51.55	Tr.	0.70	WBT 4	3.30	54.30	0.51	0.40
BFD 8	2.30	51.71	Tr.	0.60	WBT 5	1.60	54.70	0.51	0.40
BFD 9	3.10	51.66	Tr.	1.00	WBT 6	1.60	55.10	0.72	0.30
BFD 10	4.40	50.49	Tr.	1.20	WBT 7	4.30	54.10	0.62	1.10
BFD 11	3.20	50.76	Tr.	1.10	WBT 8	2.00	54.12	0.51	0.60
BFD 12	2.80	52.40	Tr.	0.90	WBT 9	2.20	53.53	0.50	0.60
BFD 13	5.90	49.68	Tr.	1.20	WBA 1	22.00	41.50	0.36	1.90
BFD 14	2.40	52.10	Tr.	1.00	WBA 2	10.50	48.50	0.37	1.20
Caliche at base of hill, Big Flat deposit					WBA 3	5.50	51.60	0.39	1.10
BF 1	10.5	52.00	0.68	3.00	WBA 4	5.10	52.00	0.41	1.20
BF 2	12.50	46.2	0.72	3.00	WBA 5	33.00	36.60	0.42	1.90
BF 3	12.2	45.05	0.46	3.74	BLUE DEPOSIT				
BF 4	9.75	48.55	0.72	2.62	B 1	2.00	53.70	0.34	0.70
BF 5	12.1	44.1	2.25	3.85	B 2	16.00	31.25	12.00	1.00
BF 6	23.9	35.95	0.46	6.3	B 3	2.15	49.35	3.90	0.80
BF 7	20.35	40.06	0.52	3.2	B 4	0.95	54.05	0.90	0.55
BF 8	21.35	38.00	Tr.	3.35	B 5	1.70	40.20	11.00	1.30
BF 9	26.0	28.02	0.58	2.9	B 6	2.55	53.20	0.50	0.90
BF 10	20.2	37.05	0.52	6.75	B 7	3.30	49.90	1.90	0.70
BF 11	15.23	40.02	0.68	2.77	B 8	2.00	53.60	1.20	0.40
BF 12	13.25	45.00	0.93	2.73	B 9	2.20	53.50	0.39	0.45
BF 13	11.70	42.45	0.07	6.9	BA 1	3.90	53.00	0.11	1.10
BF 14	8.00	51.05	0.07	4.7	BA 2	3.50	53.00	0.34	1.20
BF 15	11.60	45.1	0.19	4.4	BA 3	0.60	33.10	18.96	0.90
BF 16	20.20	36.35	0.68	10.75	BA 4	0.60	40.10	12.96	0.40
DRY TROUGH DEPOSIT					BA 5	3.20	53.10	0.07	0.80
DT 1	6.1	33.60	1.37	1.6	BA 6	3.10	53.80	0.05	0.70
DT 2	3.7	51.30	0.50	1.4					
DT 3	3.3	51.71	0.42	1.6

Photo 10. Hamilton limestone deposit, upper prospect quarry, showing massive white crystalline limestone (left) and decomposed granite. Exploration tunnel (center) runs westerly (toward left) through limestone cut by granitic dikes.

limestone is similar to the rest of the deposit, being white and coarse crystalline. Recent surface development has obliterated much of the old quarry, but the limestone is exposed over a width of 60 feet and height of 45 feet on the remaining face. The limestone apparently supplied the two vertical stone lime kilns located close by on Harlan Creek. Reserves of the two southern lenses have not been determined but may aggregate 500,000 tons or more.

Based on the chemical composition and the obvious whiteness of the limestone, the Hamilton deposit may prove useful as white filler, in glass manufacture, or for other special purposes. In all probability, the deposit would have to be mined selectively or beneficiated or both in order to obtain a substantial production of a uniform, high-quality product. Accessibility is good via an improved dirt road, but rail facilities are about 18 miles away at Hollister.

Other references: Aubury, 1906, p. 76; Loizure, 1926, p. 237; Logon, 1947, p. 274-277; Bowen and Gray, 1959, p. 38.

Harmony Hills deposit. Location: SW $\frac{1}{4}$ sec. 17 (proj.), T. 13 S., R. 5 E., M.D., 5 miles southwest of Hollister; Hollister 15-minute quadrangle. Ownership: Howard Harris, 7800 Cienega Road, Hollister (1966).

The Harmony Hills deposit is a small body of limestone that may be of economic interest in the near future because of its white color and easy accessibility. The body is lenticular in plan, striking northwest along the crest of a small hill through a relief of 60 to 80 feet. It is at least 500 feet long and has a maximum width of about 100 feet. Typically, the limestone is white, medium to very coarse crystalline, and high in calcium. There is local blue-gray mottling, and some of the limestone is stained yellowish brown along fractures and joints. Granitic rocks cut the deposit in several places and probably comprise the country rock.

A typical clean limestone sample shows 52.37% CaO, 2.60% MgO, 0.32% SiO₂, 0.08% Fe₂O₃, 0.14% Al₂O₃, and 0.01% P₂O₅ (Bowen and Gray 1959, p. 25).

Photo 11. Hamilton deposit, lower quarry, showing eastward (?) dipping massive limestone flanked by decomposed granitic intrusive. This quarry was worked between 1890 and 1907 as source of white coarse-crystalline limestone calcined at nearby kiln.

Photo 12. Old lime kiln (circa 1890) along Harlan Creek near lower quarry of Hamilton limestone deposit.

Although exposures are poor and scattered, limestone reserves appear to be no more than 100,000 tons. Core drilling and sampling are needed to evaluate the deposit more accurately. Since the deposit was briefly examined by this writer in 1964, several bulldozer cuts made by the owner in 1966 show that parts of the deposit are not over a few feet thick (Oliver E. Bowen, personal communication, 1968).

Hartnell group. Location: Mainly S $\frac{1}{2}$ T. 14 S., R. 4 E., M.D., 5 to 9 miles east and northeast of Salinas; Salinas 15-minute quadrangle. Ownership: Multiple (includes Sillacci Ranch, Walter Bardin Ranch, and other properties).

The Hartnell group includes a northwest-trending series of carbonate deposits lying in the northeast part of the Salinas 15-minute quadrangle and close to the old Hartnell College property. Based largely on unpublished mapping of Oliver E. Bowen (1968), the gross distribution of the carbonate rock is shown on plate 2. Some of the masses shown are exaggerated and consist of smaller, detached lenses and bodies. The carbonate rock is associated to some extent with schist and other rocks of the Sur Series and together they occur as northwest-trending pendants in granitic rock. Based on the observations of Bowen (1968, personal communication) and of this writer, the deposits are mostly small and often consist of mixed limestone and dolomite. Some of the deposits are cut by granitic dikes.

There has been only limited development of limestone, principally (solely?) by Spreckels Sugar Company. Spreckels quarried limestone in NE $\frac{1}{4}$ sec. 20 and NE $\frac{1}{4}$ sec. 30, T. 14 S., R. 4 E. (proj.), and possibly elsewhere in the Hartnell group, for use in sugar processing and in the construction industry around the turn of the century. Several prospect pits also were developed by Spreckels in sec. 3, T. 14 S., R. 4 E. on the Walter Bardin Ranch but were never worked commercially. Production from the Hartnell deposits prior to 1905 is estimated to be more than 50,000 tons of limestone. Some limestone and associated granite probably were produced in recent years from the lower Sillacci (Spreckels) quarry in NE $\frac{1}{4}$ sec. 30 for use as crusher run base material in road construction.

Most of the carbonate deposits in the Hartnell group are too small or too impure to be of future interest, but a few deposits have not been examined carefully and warrant future consideration.

Other references: Aubury, 1906, p. 73; Bowen and Gray, 1959, p. 37; Hart, 1966b, p. 59.

Ideal Cement Company—San Juan Bautista plant. Location: SE $\frac{1}{4}$ sec. 4, T. 13 S., R. 4 E., M.D., 1 mile south of San Juan Bautista; San Juan Bautista 15-minute quadrangle. Ownership: Ideal Cement Company, 420 Ideal Cement Building, Denver, Colorado 80202.

Construction of the San Juan Bautista cement plant began in 1914 or earlier by Old Mission Portland Ce-

ment Company but was not completed until 1918. The plant employs the wet process and has been operative during the periods 1918 to 1930, 1941 to 1943, and 1947 to the present.* In 1927, the plant was acquired by Pacific Portland Cement Company, which merged in 1952 with Ideal Cement Company. Limestone utilized in the manufacture of cement has been obtained from several properties in San Benito County, including the Barbee Ranch, Bryan and Pearce-Twohy, Flint-Steinbeck, and Underwood deposits. Other nearby deposits held by Ideal Cement Company include Bird Canyon Ledge, Power Line(?), and Upper Bird Creek in San Benito County and East Gabilan in Monterey County. For deposit descriptions, the reader is referred to the above-named properties.

The San Juan Bautista plant utilizes about 220,000 tons of limestone and other raw materials per year plus 40,000 to 60,000 tons of mudstone (Monterey Formation) from a quarry near Chittenden, Santa Cruz County, to obtain the needed combination of lime, silica, alumina, and iron oxide (Bowen and Gray, 1962, pt. 2, p. 5). These raw materials are crushed, ground, blended, slurried, and converted to clinker in four conventional kilns. The plant has a rated capacity of 950,000 barrels of cement per year.

References: Aubury, 1906, p. 184; Bradley and Lagan, 1919, p. 626–630; Lagan, 1947, p. 276–277; Bowen and Gray, 1959, p. 23, 25; Bowen and Gray, 1962, pt. 1, p. 7, and pt. 2, p. 4–5.

Kaiser-Harris deposit. Location: W $\frac{1}{2}$ sec. 3 and E $\frac{1}{2}$ sec. 4, T. 14 S., R. 5 E. (proj.), M.D., 7 miles south of Hollister; Gonzales 15-minute quadrangle. Ownership: Kaiser Aluminum and Chemical Corporation, 300 Lakeside Drive, Oakland (1964).

This dolomite deposit is situated in the west corner of the Garner-Harris Ranch immediately east of the corner common to the Garner-Harris, Martin, Reeves, and McCray Ranches (named counter-clockwise). The common corner lies 2 miles west-southwest of the Almaden Winery. In 1943, Kaiser Aluminum and Chemical Corporation (formerly Permanente Metals Corporation) purchased 237 acres of dolomite property from Cassie Crowe and Howard Harris after extensive drilling and trenching (Logan, 1947, p. 279). There has been no production, and the deposit is held as reserve to Kaiser's Natividad dolomite deposit 10 miles to the west in Monterey County. Dolomite from the latter deposit is used extensively in the chemical and refractory industries.

The Kaiser-Harris dolomite is white, coarse crystalline, and comprises the bulk of a small northeast-trending pendant. The pendant is exposed over an irregular area of about 40 acres, projecting salients to the northeast and southwest. One small zone of medium- to coarse-crystalline, gray, banded limestone was noted near the projected E $\frac{1}{4}$ cor. sec. 4, and others may be present. Other deleterious features include

*The plant ceased operations in 1973, apparently due to the high cost of newly required pollution control equipment. The plant was subsequently dismantled.

numerous granitic dikes and possible schist interbeds, particularly in the topographically low areas. Two samples, one (GP-23) analyzed by Abbot A. Hanks, Inc., in 1955 and the other (KH-1) by the Division of Mines and Geology laboratory in 1964, indicate the high quality of the dolomite:

Sample	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	P ₂ O ₅	K ₂ O	Ign. loss
GP-23	0.14%	0.11%	0.17%	30.80%	21.15%	tr.	n.d.	n.d.
KH-1	1.40	0.12	0.00	31.00	20.00	0.02%	0.00%	46.10%

Sample GP-23 (Bowen and Gray, 1959, p. 35) is from the central part of the pendant and KH-1 is from a road cut in the main northeast salient.

Reserves of dolomite cannot be estimated without more data. At the crest of the low spur near the south-east boundary of the property, a drill hole reportedly bottomed in dolomite at a depth of 180 feet. Considering that the pendant is exposed through nearly 1,000 feet of relief, accessible dolomite reserves may amount to several million tons. Additional, but much smaller, reserves are available to the northeast where a lens is exposed in a roadcut near N¹/₄ cor. sec. 3.

Los Vergeles deposits. Location: N¹/₂ T. 13 S., R. 3 E. and R. 4 E., M.D., 3 to 5 miles south and southwest of San Juan Bautista; San Juan Bautista 15-minute quadrangle. Ownership: Los Vergeles Rancho in part (1959).

A series of small to medium-sized lenses and bodies of carbonate rock comprise a gently sinuous belt that lies mainly within the Los Vergeles Rancho in Monterey and San Benito Counties. The belt extends 6 miles eastward from S¹/₂ sec. 10, T. 13 S., R. 3 E. (proj.), near Crazy Horse Canyon Road, to SE¹/₄ sec. 15, T. 13 S., R. 4 E., near Queen Canyon (plate 2). The carbonate rock is associated with other metamorphic rocks of the Sur Series which occur as roof pendants in granodiorite (Allen, 1946, p. 20).

According to Bowen and Gray (1959, p. 23), the carbonate rock consists largely of crystalline limestone but is extensively contaminated with silica and dolomite. The limestone varies from coarse to fine crystalline and from blue gray to white. A select sample of white, coarse-crystalline limestone, collected from the carbonate body crossed by San Juan Grade road and analyzed by Abbot A. Hanks, Inc., in 1958, contained 55.48% CaO, 0.25% MgO, 0.18% SiO₂, 0.03% Fe₂O₃, 0.08% Al₂O₃, and 0.02% P₂O₅. In spite of the analysis, it is evident that careful sampling and selective mining would be required to develop limestone of uniform grade. The largest bodies reportedly lie at the west end of the belt near Crazy Horse Canyon.

Apparently, there has been only minor development of one of the deposits. A small tonnage of limestone was produced from a quarry along the San Juan Grade road near W¹/₄ corner sec. 18, T. 13 S., R. 4 E. (proj.). Some of this material was used by the Judson

Iron Works, presumably as a steel flux (Laizure, 1925, p. 43).

Martin Ranch deposits. Location: Secs. 32, 33 and 34, T. 13 S., and N¹/₂ sec. 4, T. 14 S., R. 5 E. (proj.), M. D., 6 to 7 miles south of Hollister; Hollister and Gonzales 15-minute quadrangles. Ownership: Martin brothers, 1215 Guarantee Savings Building, Fresno, California (1966).

Numerous small to medium-sized bodies of crystalline dolomite and limestone lie on the 2,800-acre Martin Ranch. The dolomite deposits are largely confined to the south part of the ranch in the vicinity of N¹/₂ sec. 4 (proj.). Limestone deposits lie north and northwest of there—mainly in secs. 32 and 33 (proj.). The only commercial development was by A. J. Fazzi who was preparing to ship dolomite from an unidentified deposit on the Martin Ranch in June 1916 (Bradley and Logan, 1919, p. 635-636; Logan, 1947, p. 278).

The distribution of the Martin Ranch dolomite and limestone, based largely on the detailed mapping of Thomas H. Rogers (1968, unpublished map), is indicated on plate 2.

The main dolomite deposit in NE¹/₄ sec. 4, examined briefly in February 1964, covers a north-trending area about 1,200 feet long by at least 200 feet wide. The deposit does not appear to be solid dolomite at its north end, where it is bordered and intruded by granitic rock. To the south, the dolomite gives way to limestone (see Reeves Northeast deposits). Most of the dolomite is white and medium to very coarse crystalline. There is some iron oxide staining along joints and fractures; otherwise, the dolomite appears to be of uniform, high quality. The deposit was explored in 1956 by Westvaco Mineral Products Division, FMC Corporation, who made five or six bulldozer cuts across the long axis of the body. Four chemical analyses of dolomite from the cuts were made by Abbot A. Hanks, Inc., in 1958 (Bowen and Gray, 1959, p. 35) and show the material to be of high quality:

Sample	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	P ₂ O ₅
MD 1.....	0.26%	0.02%	0.06%	29.75%	22.19%	0.02%
MD 2.....	0.18	0.05	0.04	29.57	22.35	0.02
MD 3.....	0.44	0.01	0.08	29.71	22.13	0.01
MD 4.....	0.32	0.06	0.10	29.91	21.98	0.03

Another body of dolomite, exposed immediately to the west, covers an irregular east-trending area with maximum areal dimensions of 900 feet by 600 feet. According to Thomas H. Rogers (1968, personal communication), who mapped the northern part of the mass, the dolomite is nearly white, coarse crystalline, and pure. The outcrop pattern of the dolomite suggests that the mass dips gently to moderately to the north.

Dolomite reserves of the above deposits are undetermined but could amount to several million tons. The two dolomite deposits are reasonably accessible and well situated for mining, being exposed through 200 to 300 feet of relief.

The main limestone deposits are centered on "hill 1981" about a mile north of the dolomite deposits. Perhaps the largest limestone deposit covers an east-trending area about 600 feet long by 300 feet wide on "hill 1981." Part of this deposit is well exposed, consisting of blue-gray, medium- to coarse-crystalline limestone. According to Oliver E. Bowen (1968, personal communication), lenticular replacement patches of dolomite a few inches thick and several feet long are present but do not appear to make up a substantial volume of the mass. Patches and laceworks of siliceous material indicate a probable silica content of 2 to 5%.

Many smaller lenses are present in the vicinity of "hill 1981" and southwest of there (plate 2). Some of these consist of relatively pure limestone and others contain substantial amounts of dolomite and siliceous impurities. Because of the apparent small sizes of these limestone bodies and the abundance of quartz-mica schist interbeds and granitic dikes, only three or four of the larger bodies seem worthy of prospecting. Maximum reserves of economically recoverable limestone probably do not exceed 1 or 2 million tons. None of the Martin Ranch deposits had been explored by drilling as of June 1969 (Thomas H. Rogers, 1969, personal communication).

Other reference: Taliaferro, 1943, map.

McCray Ranch deposits. Location: E $\frac{1}{2}$ sec. 4, T. 14 S., R. 5 E., M. D., 7 $\frac{1}{2}$ miles south of Hollister; Gonzales 15-minute quadrangle. Ownership: Dr. Rollin Reeves, Salinas (1964).

A nearly continuous succession of detached masses of dolomite extend for half a mile in a northeast-trending zone in SE $\frac{1}{4}$ sec. 4. Actually, these masses may be remnants of a single pendant connected with the Kaiser-Harris deposit to the northeast which is now cut in numerous places by granitic rock.

Several salients of dolomite and a small zone of limestone extend to the southwest into the McCray Ranch from the Kaiser-Harris pendant and, with one exception, none appears to be of sufficient size to be economic. One salient of dolomite extends to the south where it connects with a mass of dolomite that extends about half a mile southwest to the edge of the Reeves Ranch. The dolomite mass appears to be cut by numerous granitic dikes so that it may actually consist of a number of small disconnected masses of dolomite. Much of the dolomite is white and of good quality. During the early 1960s, the deposit was drilled and acquired by Inorganic Chemicals Division of FMC Corporation. Reserves of dolomite may be fairly large, although considerable granitic material is probably present.

No chemical analyses of the dolomite are available. However, two samples of limestone collected at the ridgecrest near E $\frac{1}{4}$ cor. sec. 4 were shown to be of high grade, based on chemical analyses by Abbot A. Hanks, Inc. (Bowen and Gray, 1959, p. 36). The limestone is

medium to coarse crystalline, light gray to blue gray, banded, and platy. The limestone mass is probably too small to be of significant commercial value.

McPhail deposit. Location: SE $\frac{1}{4}$ sec. 13, T. 14 S., R. 5 E. and SW $\frac{1}{4}$ sec. 18, T. 14 S., R. 6 E., M.D., 10 miles south-southeast of Hollister; Gonzales 15-minute quadrangle. Ownership: Amy McPhail of Hollister and others.

An undeveloped deposit of crystalline carbonate rocks of the Sur Series is shown by R. E. Dempster (unpublished mapping shown in Jennings and Strand, 1958) as occupying the summit of a 2,240-foot hill. The deposit is shown to trend northwest and to cover an irregular area of half a mile by a quarter of a mile. From a distance, the deposit appears to consist of several detached masses of carbonate rock as indicated by sporadic outcrops. Close examination is needed to determine the nature of the deposit and the advisability of additional prospecting. Dirt roads lead from Cienega Valley, via Indian Canyon or Thompson Creek, to within half a mile of the deposit on the west and south. The deposit is referred to in the literature as the McPhail or Archer Lime Company deposit of sec. 13 but has never been described in detail.

References: Bradley and Lagan, 1919, p. 640; Laizure, 1926, p. 237; Averill, 1947, p. 52; Lagan, 1947, p. 276; Bowen and Gray, 1959, p. 38.

Melendy Ranch (Willow Creek) deposit. Location: S $\frac{1}{2}$ sec. 21, NE $\frac{1}{4}$ sec. 28 and W $\frac{1}{2}$ sec. 27, T. 15 S., R. 7 E., M.D., 20 miles southeast of Hollister; San Benito 15-minute quadrangle. Ownership: George Melendy Ranch and others (1947).

Crystalline limestone of the Sur Series lies along the San Andreas fault zone as a series of broken masses and slivers which constitute the Melendy Ranch deposit. These masses cover an area 1 $\frac{1}{2}$ miles long by a maximum of 500 feet wide and extend southeast of the highway bridge in sec. 21. Most of the limestone is blue gray to white, somewhat siliceous, and strongly brecciated—the breccia fragments ranging in length from a few inches to 50 feet or more. The breccia is partly cement with calcite, but many of the fractures are filled with "mountain leather" (matted, fibrous asbestos) and other impurities. Noncarbonate metamorphic and sedimentary rocks are intermixed to varying degrees with the limestone blocks and masses, rendering most of the deposit impure. A composite sample of limestone collected across a width of 75 feet near the south end of the deposit by Logan (1947, p. 275) and analyzed by Abbott A. Hanks, Inc., showed 92.08% CaCO₃, 2.99% MgCO₃, and 4.59% SiO₂.

Although total reserves are probably fairly large, most of the limestone is too intermingled with other rocks to be extracted without extensive selective mining and beneficiation. Relatively pure limestone appears to be available only in blocks and small masses. There had been no work done on the property as of

October 1962, and the limestone probably is only of local interest.

Other references: Wilsan, 1943, p. 193, plate 3; Bowen and Gray, 1959, p. 39.

Middle Dam deposit. Location: N $\frac{1}{4}$ sec. 29 (proj.), T. 13 S., R. 5 E., M. D., 5 to 5 $\frac{1}{2}$ miles southwest of Hollister; Hollister 15-minute quadrangle. Ownership: Howard Harris, 7800 Cienega Road, Hollister (1964).

This deposit consists of mixed carbonate rock exposed discontinuously for about a mile along the north wall of North Canyon. Much of the rock is white, very coarse-crystalline limestone and dolomitic limestone. It occurs as thin, steeply dipping, discontinuous lenses interbedded with schist and commonly cut by granitic dikes. One of the largest lenses, at the east end of the deposit, is reported to be an average of 30 feet thick by 300 feet long (Oliver E. Bowen, 1964, personal communication). Analyses of three samples collected by Bowen and Harris are given below. The first one (GP-24) was analyzed by Abbot A. Hanks, Incorporated, in 1954 (Bowen and Gray, 1959, p. 32). The others were analyzed by the Division of Mines and Geology laboratory in 1964.

Sample	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	P ₂ O ₅	K ₂ O	Ign. loss
GP-24	0.52%	0.08%	0.16%	43.17%	10.32%	tr	n.d.	n.d.
MD-1.....	1.60	0.06	0.00	54.00	0.61	0.04%	0.00%	42.6%
MD-2.....	5.40	0.58	0.90	42.80	11.10	1.00	0.10	36.8

Carbonate rocks of the Middle Dam deposit appear to be of mixed chemistry and limited reserves. However, some of the material may be of economic interest because of its whiteness and proximity to market.

Other reference: Taliaterra, 1948, map.

Mount Harlan deposit. Location: Sec. 22, T. 14 S., R. 5 E., M.D., 11 miles south of Hollister; Gonzales 15-minute quadrangle. Ownership: Not determined. This deposit is referred to as the Hamilton deposit by Bowen and Gray (1959, p. 38), apparently based on interpretable data presented by Logan (1947, p. 275). However, the location of the Hamilton deposit is shown by Averill (1947, p. 51-52) to be near the lime kiln in sec. 23 and is described that way herein.

Data from U.S. Steel Corporation (*in* Jennings and Strand, 1958) indicates that a northwest-trending, lenticular mass of crystalline limestone caps the 3,262-foot-high Mount Harlan. The mass is shown to be 4,000 by 1,200 feet in maximum dimensions and is bordered by granitic rocks. An average of 33 analyses of samples collected by U.S. Steel at 5-foot intervals across the strike of the main part of the mass is reported to be 52.22% CaO, 2.60% MgO, 0.75% SiO₂, and 0.64% Al₂O₃ and Fe₂O₃ (Bowen and Gray, 1959, p. 38). The indicated size and quality of the deposit would seem to warrant further examination. Howev-

er, no limestone was observed during aerial reconnaissance of the Mount Harlan area (Oliver E. Bowen, 1967, oral communication). The mountain is accessible from the south via an unimproved dirt road and trail from Thompson Valley.

Natividad (Kaiser) deposit. Location: NW $\frac{1}{4}$ sec. 1 and NE $\frac{1}{4}$ sec. 2, T. 14 S., and SE $\frac{1}{4}$ sec. 35 and SW $\frac{1}{4}$ sec. 36, T. 13 S., R. 3 E., M.D. (proj.), 6 miles northeast of Salinas and 1 mile north of Natividad; Salinas and San Juan Bautista 15-minute quadrangles. Ownership: Kaiser Aluminum and Chemical Corporation, 300 Lakeside Drive, Oakland (1963).

Early development of the Natividad deposit is not clearly recorded in the literature, but it is probable that some of the small dolomite producers listed by Laizure (1925, p. 36) obtained dolomite here intermittently from 1900 to 1925. By 1926, Pacific Coast Steel Company (succeeded by Bethlehem Steel Company in 1937) began quarrying dolomite for use as a refractory near the north end of the Natividad pendant, near SE cor. sec. 35. The operation was more or less continuous until 1944, when the company ceased production. In 1942, Kaiser Aluminum and Chemical Corporation (then known as Permanente Metals Corporation) opened a dolomite quarry and processing plant half a mile to the south in the same deposit. This plant supplied calcined dolomite which was reacted with seawater at Moss Landing in order to produce magnesia. Magnesia was used for making magnesium metal at their Permanente plant in Santa Clara County until 1945. Calcined dolomite also was shipped directly to a company plant in Manteca, San Joaquin County, for the manufacture of magnesium metal between 1942 and 1944.

The demand for metallic magnesium was greatly reduced by 1945, thereby critically decreasing the need for Natividad dolomite. To offset the decrease, a refractory brick plant was constructed next to the Moss Landing seawater magnesia facility. This permitted the company to utilize large amounts of magnesia (and dolomite) and at the same time to provide industry with a wide variety of refractory products. Another operational change was made at the Natividad plant in 1952 when a heavy-media separation unit was installed to beneficiate the dolomite. In addition, the Moss Landing facilities have been expanded several times.

The Natividad deposit is a large irregular pendant of crystalline dolomite within the Santa Lucia Granite. The pendant is exposed over nearly three-quarters of a square mile of area (plate 2) and about 700 feet of relief (Allen, 1946, plate 1). The internal geology of the mass is complex, the dolomite body having been penetrated by numerous irregular dikes and sills of granitic rock that is now largely decomposed. Additional fracturing and shearing has made it virtually impossible to selectively quarry high-grade dolomite on a large scale. The composition of the dolomite is

Photo 13. High-angle oblique aerial view to east of Natividad dolomite quarry and plant in Monterey County, 1968. Crystalline dolomite of the Sur Series is obtained from multi-level quarry (top, center), crushed, washed, screened, and beneficiated by heavy-media separation (center) and finally crushed, screened, and calcined at processing plant (bottom). Dolomite quarry is largest in California. *Photo courtesy of Kaiser Refractories.*

further complicated by silica and silicate minerals implaced along shear planes and adjacent to dikes. Where free from granitic and silicic impurities, the rock is uniformly white, medium- to coarse-crystalline, relatively pure dolomite. The company provided the following typical analyses for dolomite produced in 1962: 31.75% CaO, 20.30% MgO, 1.31% SiO₂, 0.20% Fe₂O₃, 0.35% Al₂O₃, and 46.09% CO₂. Except for the subordinate production of exceptionally white material for roofing and landscaping granules, none of the dolomite is selectively quarried. A relatively high-quality, uniform product is maintained, however, by heavy-media separation and other practices. It is estimated that approximately half of the mined material is wasted.

Kaiser Aluminum and Chemical Corporation has developed the Natividad quarry by two adjacent series of benches (levels) cut into the western side of the

hill. In the northern quarry area, the 700- and 775-foot levels are the most active. The 850-foot bench was nearly worked out, and the 625-foot bench was inactive when the quarry was last examined in September 1963. In the south part of the quarry, the 750- and 825-foot levels are worked to some extent, the others being inactive. The highest level at 900 feet was worked out. It was estimated that work on the lower quarry levels would have to be resumed around 1970 at the 1963 rate of production.

Benching is conducted at 75-foot intervals in each quarry area. The faces are blasted using ammonium nitrate in 9-inch diameter holes drilled vertically by rotary methods to 85 feet. Generally, a total of 30 to 40 holes are drilled on 25-foot centers and arranged in three parallel rows for each blast. Each blast commonly yields a 2- to 3-month supply of rock. Some secondary blasting is necessary to reduce the larger blocks.

Photo 14. Natividad dolomite processing plant situated at base of hill below quarry (out of picture, top left). Washing, screening and heavy-media separation section located upper left. Beneficiated dolomite is stockpiled below (lower left) for final crushing, screening and calcining (center). Photo courtesy of Kaiser Refractories.

The rock is loaded by two $4\frac{1}{2}$ -cubic-yard capacity, electrically powered shovels into large-capacity dump trucks which haul a short distance to the large primary crusher located at the 700-foot level. Much of the decomposed granitic rock is wasted as the rock is fed over a grizzly to the jaw crusher. The material is crushed to about minus 4 inches then passed over a half-inch mesh screen where the fines, including some granitic material, are wasted. The coarse rock is next conveyed to a stockpile at the washing heavy-media separation sections located about 250 feet lower in elevation.

At the washing section, the dolomite is scrubbed in a Harding mill and passed through an attached trommel screen, both of which are supplied with fresh wash-water. Rock larger than $3\frac{3}{4}$ inches is sent to a secondary jaw crusher and recycled to the scrubber. The minus fraction is washed over a $\frac{1}{8}$ -inch mesh screen, the fines going to a thickener and then to a waste pile. The plus $\frac{3}{8}$ -inch dolomite is next conveyed to the heavy-media separation section for additional beneficiation. At this point, virtually all of the decomposed granite and other "soft" impurities have been removed from the rock.

The heavy-media separation (H.M.S.) section was added to the processing plant in 1952 to remove the

harder, siliceous and granitic impurities so that a high-quality dolomite product could be obtained. This H.M.S. process has been described in detail by Lenhart (1953, p. 89-93), Utley (1952, p. 94-96), and others. The heavy medium is a suspension of finely divided ferrosilicon and magnetite in water which is kept at a specific gravity of 2.7. Impurities lighter than 2.7 are floated off and join the sludge from the thickener and are wasted (the lightweight impurities actually appear to be very sound and probably would be useful as aggregate for structural purposes). The heavier and purer dolomite fragments (maximum specific gravity —2.85) sink in the heavy medium and are removed from the H.M.S. cone by an air lift. Next, the heavy fraction is washed over a screen and conveyed to the stockpile at the calcining plant below. The ferrosilicon and magnetite are reclaimed from the heavy medium by a sequence of steps including magnetizing, thickening, magnetic separation, and demagnetizing.

At the calcining plant, the dolomite is crushed and screened to $\frac{1}{2}$ - by $\frac{3}{4}$ -inch and minus $\frac{1}{2}$ -inch sizes for calcining in one of three gas-fired rotary kilns. Two of the kilns are used to make caustic calcined dolomite; the third, to make deadburned dolomite. Most of the calcined dolomite is shipped in 25-ton trucks to the company's seawater magnesia plant at Moss Landing.

The rest of the calcined dolomite, some of which is hydrated, is used extensively in several forms by the chemical, building, and agricultural industries.

Deadburned dolomite is produced by adding iron in the form of mill scale to the dolomite feed and burning at temperatures as high as 3,300° F. This product is shipped in bulk or bags for use as a fettling material in electric and open hearth steel furnaces.

Dolomite for roofing and landscape uses is selectively quarried and processed separately in order to obtain a uniformly white material. Crushed dolomite also is sold to the steel industry for use in maintaining open-hearth furnaces. In addition, dolomite fines from the crushing plant are used for marking athletic fields and for soil conditioning. Some of the waste material is sold for use in road construction, and a small sand plant was recently installed to process the waste fines.

Production of dolomite (excluding waste rock) at Natividad during the last decade has been between a quarter- and a half-million tons annually. Total production through 1968 is estimated to be approximately 8½ million tons. Reserve figures are not available, but based on the areal size of the deposit, dolomite reserves (including waste rock) may be on the order of 1 million tons per foot of depth.

Other references: Allen, 1946, p. 68–72; Logon, 1947, p. 197, 256–257; Bowen and Gray, 1959, p. 25; Harl, 1966b, p. 55–59.

Palmtag-Harris deposits. Location: SE¼ sec. 35, SW¼ sec. 36, T. 13 S., R. 5 E., and NW¼ sec. 1, T. 14 S., R. 5 E., M.D., 6½ miles south of Hollister and immediately southwest of Cienega Road; Hollister 15-minute quadrangle. Ownership: Howard Harris, 7800 Cienega Road, Hollister, owns the old Leopold Palmtag property (1962).

The Palmtag-Harris deposits are situated on the north and east sides of a 1,612-foot ridge partly defined by Bonanza Gulch on the west and the San Andreas fault zone on the northeast. The deposits include two moderate-size masses (Vineyard School, Hightop) and several smaller ones (including Hayfield) as indicated on plate 2. However, soil, caliche, and vegetation effectively mask the deposits, except at the west end of the Vineyard School mass. Crystalline limestone and subordinate dolomite constitute the deposits, which appear to be pendants in granodiorite. Granitic dikes also cut the deposits in many places. Brecciation and mixing of different rock types is common, the intensity increasing toward the San Andreas fault zone. The limestone is blue gray to off white, medium to coarse crystalline, faintly banded or brecciated, and sometimes siliceous. Some off-white, medium-crystalline dolomite was noted, particularly along the ridge crest southeast of the 1,612-foot hill, and may be present elsewhere. The chemistry of the limestone is suggested by the analyses shown in table 14. The analyses shown by Bowen and Gray (1959, p. 36) for the Palmtag-Harris deposits are actually from a deposit a mile to the northwest in NW¼ sec. 34

(proj.) (Oliver E. Bowen, 1963, personal communication).

Limestone reserves probably amount to several million tons. However, considering the variable quality of the limestone, its main use would appear to be for cement manufacture. Even so, some selective mining would be necessary to avoid dolomitic zones and excessive siliceous or granitic material. The main advantages of the limestone are that it is easily accessible and close to other limestone deposits. Also, it is only 10 or 11 miles by road southeast of the cement plant near San Juan Bautista. According to Laizure (1926, p. 234), some dolomite was quarried on the Palmtag Ranch long ago, but the location of the quarry is not known.

The three deposit areas prospected and sampled in recent years, mostly by the owner, are described in additional detail below.

Vineyard School deposit. This deposit is located a quarter of a mile southwest of Vineyard School at the northwest end of the ridge. It covers an east-trending, teardrop-shaped area with maximum dimensions of 1,000 feet by 600 feet and a relief of about 200 feet. The limestone is blue gray to white, medium to coarse crystalline, and brecciated. No dolomite was observed, but granitic salients commonly cut the deposit. The only surface samples analyzed were obtained from a bold ledge at the west end of the deposit. These analyses (F-H-1 to 10, table 14) show the ledge to be of relatively good quality. However, lower quality limestone and the presence of numerous granitic dikes are indicated in prospect cuts and drill holes made in the 1950s by U.S. Steel Company. As drill data show the deposit to extend to a depth of at least 180 feet, limestone reserves, including granitic intrusives, are estimated to be about 3 million tons.

Hightop deposit. The deposit is located high on the northeast side of the main ridge 2,000 feet south of Vineyard School. Although exposures are poor, prospect cuts reveal the presence of carbonate rock over a west-northwest-trending area about 1,600 feet long by a maximum of 300 feet wide. Granitic rock also is exposed in the cuts, and the deposit may consist of several small masses. Most of the limestone is off white to blue gray, medium to coarse crystalline, and faintly banded. Some crystalline dolomite is present along the southwest margin of the deposit, as well as farther southeast along the ridge crest where no limestone was observed. Analyses of 14 samples (see HT samples, table 14) indicate the limestone to be siliceous and otherwise impure. The dolomite was not sampled for analysis. More work is needed to determine the quality and size of the deposit.

Hayfield prospect. Small broken masses of limestone lie in an area of low relief in the San Andreas fault zone a third of a mile southeast of Vineyard School. These are poorly exposed but have been pros-

Table 14. Chemical Analysis of Palmtag—Harris Deposits, San Benito County

Sample	Fe	SiO ₂	Al ₂ O ₃	CaO	MgO	S	P	Mn	R ₂ O ₃	Loss
VINEYARD SCHOOL DEPOSIT *										
F-H-1.....	0.17%	2.40%	0.40%	53.61%	0.72%	0.010%	0.030%	0.01%	0.64%	42.63%
F-H-2.....	0.35	2.18	0.40	52.60	0.71	0.007	0.030	0.01	0.90	43.40
F-H-3.....	0.40	2.80	0.43	52.40	0.72	0.007	0.040	0.02	1.00	41.90
F-H-4.....	0.20	1.70	0.11	54.20	0.47	0.006	0.050	0.01	0.40	43.40
F-H-5.....	0.30	1.80	0.27	54.00	0.80	0.007	0.030	0.01	0.70	43.12
F-H-6.....	0.20	2.00	0.30	54.60	0.84	0.010	0.040	0.01	0.56	42.10
F-H-7.....	0.10	0.60	0.16	53.90	1.36	0.007	0.030	0.01	0.30	43.25
F-H-8.....	0.15	2.80	0.19	51.80	1.80	0.010	0.020	0.01	0.40	43.40
F-H-9.....	0.10	1.06	0.16	52.90	0.86	0.007	0.027	0.01	0.30	45.20
F-H-10.....	0.20	0.70	0.12	54.50	1.11	0.007	0.012	0.01	0.40	44.00

HAYFIELD DEPOSIT *

Sample	SiO ₂	Fe ₂ O ₃ & Al ₂ O ₃	CaO	MgO
HF 1.....	4.67%	0.70%	53.70%	0.34%
HF 2.....	2.28	1.00	51.25	1.20
HF 3.....	2.81	0.47	51.50	0.31
HF 4.....	2.00	0.47	54.55	0.32
HF 5.....	0.92	0.14	55.45	0.30
HF 6.....	1.38	0.21	55.00	0.28
HFA 1.....	3.80	1.30	48.16	3.70
HFA 2.....	1.10	0.60	54.44	0.50
HFA 3.....	1.30	0.40	54.78	0.40
HFA 4.....	0.60	0.30	54.00	0.90
HFA 5.....	2.70	1.20	52.86	0.50
HFA 6.....	1.80	0.80	53.48	0.36
HFA 7.....	1.00	0.50	54.54	0.30
HFA 8.....	2.30	1.10	49.23	3.00
HFA 9.....	2.30	0.90	53.45	0.36
HFA 10.....	2.50	0.80	53.74	0.30

HIGHTOP DEPOSIT **

HT 1.....	16.62	3.60	43.50	0.21
HT 2.....	10.15	1.50	48.60	0.34
HT 3.....	7.25	2.00	49.30	0.46
HT 4.....	22.55	3.20	41.00	0.19
HT 5.....	18.25	4.00	42.15	0.93
HT 6.....	10.80	2.55	47.55	0.61
HT 7.....	11.25	2.30	47.50	0.54
HT 8.....	8.60	1.65	55.75	0.37
HT 9.....	4.50	1.10	51.30	1.26
HT 10.....	17.00	2.63	44.40	0.61
HT 11.....	32.20	5.01	33.50	0.68
HT 12.....	16.25	4.20	42.80	0.79
HT 13.....	14.25	3.70	45.15	0.47
HT 14.....	14.95	3.15	45.10	0.57

* Samples collected from resistant ledge at west end of deposit, analyzed by U.S. Steel

** Samples collected from prospect cuts, analyzed by Howard Harris, owner.

pected by means of several cuts and are shown to be 500 feet long and less than 100 feet wide. The limestone is typically blue gray, medium to coarse crystalline, and highly brecciated. Analyses of 16 chip samples (HF and HFA series in table 14), taken at 50-foot intervals along the strike of the prospect, show the limestone to be of general good quality. The prospect appears to be too small to be of significant economic interest.

Other reference: Bradley and Logan, 1919, p. 635.

Porter deposit. Location: W½ sec. 7, T. 14 S., R. 4 E. (proj.), M.D., 1¼ miles east of Natividad; Salinas 15-minute quadrangle. Ownership: James Porter, 701 Old Stage Road, Salinas (1959).

An undeveloped dolomite deposit 1½ miles east of Natividad was described by Bowen and Gray (1959, p. 28) as roughly 300 feet wide and 3,000 feet long, with an eastward elongation and nearly vertical dip. Granitic intrusions penetrate the mass in many places. Most of the rock is white, medium-crystalline dolomite similar to that in the Natividad (Kaiser) deposits. Three channel samples cut perpendicular to the strike probably reflect the chemistry of the deposit.

Sample	Fe %	SiO ₂ %	Al ₂ O ₃ %	CaO %	MgO %	S %	P %	Mn %	R ₂ O ₃ %	CO ₂ & H ₂ O %
1.....	0.10	1.52	0.38	41.20	11.20	0.004	0.010	0.06	0.52	45.64
2.....	0.40	0.68	0.30	31.00	20.67	0.003	0.008	0.05	0.90	45.10
3.....	0.20	0.84	0.21	32.00	20.35	0.003	0.006	0.05	0.50	46.53

The deposit was later mapped in detail by Bowen (1968, unpublished map) and shown to consist of mixed dolomite and limestone. Bowen also mapped three other fairly large bodies of mixed limestone and dolomite within half a mile to the north and west (see plate 2).

Power Line deposits. Location: SW¼ sec. 4, SE¼ sec. 5, E½ sec. 7, and sec. 8, T. 14 S., R. 5 E. (proj.), 7½ to 9 miles south-southwest of Hollister; Gonzales 15-minute quadrangle. Ownership: Dr. Rollin Reeves, Salinas (part of mineral rights to Ideal Cement Company?) (1964).

The Power Line deposits, referred to by Bowen and Gray (1959, p. 32), extend southwest from SW¼ sec. 4 to E½ sec. 7. They were named for the power line that crosses the northern portion of the deposit group. The deposits are situated on the ridges and rolling upland surfaces that divide the three drainages of Pescadero, Bird, and Swamp Creeks. Brief examination of the deposits by Bowen and Hart in February 1964 indicated that none of the carbonate masses are large and that some of the limestone is impure. The largest mass seen was about 1,000 feet by 700 feet in plan and was exposed over 200 feet in relief. Much of the lime-

stone is medium to coarse crystalline and light blue gray, but some is locally siliceous and dolomitic. The great majority of carbonate bodies in the northeastern two-thirds of the group are small and scattered (the southwestern end of the Power Line group was not examined). Although limestone reserves may amount to several million tons or more, the deposits have not been sampled or carefully examined, and little can be said of the chemistry of the deposits.

Quail Creek deposit. Location: N $\frac{1}{2}$ sec. 7, T. 15 S., R. 5 E., M.D., 6 miles northeast of Chualar; Gonzales 15-minute quadrangle. Ownership: Hazel Hurt, Salinas (1960).

At the west end of the Quail Creek deposit, adjacent to Quail Creek, a series of small quarries was worked as a source of limestone for lime in the early 1900s. It is quite possible that these quarries were operated by J. C. Jens, who reportedly produced limestone from near Chualar from 1910 to 1913 (unpublished records), or by Spreckels Sugar Company, which operated in the vicinity prior to 1910 (Laizure, 1925, p. 43). Apparently, the deposit then lay idle until 1959, when Barnes Construction Company of San Marino developed a large quarry on the south slope of the ridge just east of the first development. In April 1960, this operation was inactive, although stockpiles and equipment remained at the quarry (Hart, 1966b, p. 60).

This deposit consists of several narrow lenses or beds of carbonate rock that extend nearly a mile eastward from Quail Creek and dip 30° to 50° S. The beds are interleaved locally with schist, and the whole has been penetrated by granitic dikes and sills. The main lens attains an estimated maximum thickness of 150 feet, including schist and granitic salicnts, but is much thinner at its extremities. Because the carbonate beds dip more or less parallel to the southwest slope of the ridge, the deposit appears to be much larger than it actually is. It consists of nearly white, fine- and coarse-crystalline calcite and medium-crystalline dolomite, which occur together in varying proportions to form limestone, dolomitic limestone, and dolomite. According to Bowen and Gray (1959, p. 37), the western third of the deposit consists of mixed carbonate rock but the eastern two-thirds appears to be mainly limestone.

Barnes Construction Company first developed the deposit in early 1959 by stripping the soil and caliche cover and by trenching and drilling, reportedly blocking out 2 million tons of rock. This was followed by quarrying later in 1959 and possibly in early 1960. The quarry, which is more than 1,000 feet long and has an estimated maximum relief of 150 feet, is located in the western half of the deposit. The face, which probably slopes an average of 40°, is irregularly benched. By means of cut and fill, the quarry floor has been extended 200 to 300 feet out from the toe of the face. Although the quarry was not active when visited in

April 1960, the limestone apparently had been quarried somewhat selectively and transported to a bench about 20 feet above the quarry floor. By passing the broken rock over a grizzly or grate on an inclined chute from the bench to the quarry floor, some of the decomposed granitic and other deleterious fines were removed. The material was subsequently crushed and screened with portable equipment, stored in open piles, and sacked for shipment. In April 1960, there were six conical piles of crushed rock ranging from 10 to 20 feet high and containing rock ranging from plus 6-inch to minus $\frac{1}{8}$ -inch fines. In addition, several thousand sacks of roofing granules ($\frac{3}{8}$ by $\frac{1}{8}$ inch) and landscape rock ($\frac{1}{4}$ by $\frac{3}{8}$ inch) were stacked on pallets, and several pieces of portable equipment (scraper, loader, fork-lift, conveyor, and sacking machine) remained at the quarry.

Based on observations at the quarry, production would appear to be fairly large. However, much of the material apparently was used to construct a road to the quarry. Unpublished records show that only a modest amount of carbonate rock was sold for landscape and roofing purposes.

Reserves of the Quail Creek deposit are difficult to estimate because the dimensions of the carbonate bodies are not sufficiently known. Perhaps several million tons of carbonate rock could be quarried here; but the proportion, quantity, and quality of limestone and dolomite available are undetermined. A chemical analysis of a grab sample taken from one of the stockpiles suggests that dolomite predominates in the quarry area. The analysis, made by Lydia Lofgren of the Division of Mines and Geology in 1962, showed 17% MgO, 36.25% CaO, 2.4% Fe₂O₃, and 0.42% SiO₂. Although heterogeneous in composition and color (some iron-staining), most of the carbonate rock is physically sound and probably suited to various construction, roofing, and landscaping uses.

Reeves Northeast deposits. Location: Sec. 4, T. 14 S., R. 5 E., M.D., 7 $\frac{1}{2}$ miles south of Hollister; Gonzales 15-minute quadrangle. Ownership: Dr. Rollin Reeves, Salinas (1964).

A number of small to medium-sized masses of limestone and dolomite lie along the northeast-trending ridge in the east or northeast part of the Reeves Ranch. Two of the better quality limestone deposits lie at the ridge crest close to the corner common to the Martin, Kaiser-Harris, and McCray (Reeves) properties. The largest and most northeasterly deposit, which lies partly on the Martin and McCray Ranches, is roughly 1200 feet long by 700 feet wide. It consists of blue-gray, medium-crystalline, banded limestone that weathers into platy fragments. An analysis of a typical sample showed 52.67% CaO, 1.41% MgO, 1.56% SiO₂, 0.17% Fe₂O₃, 0.95% Al₂O₃, and 0.03% P₂O₅ (Bowen and Gray, 1959, p. 36).

Judging from the outcrops, the deposit appears to be gently dipping and probably contains less than 1 mil-

lion tons of limestone. A similar but smaller deposit caps the knoll a few hundred feet to the southwest. Other small limestone deposits are scattered through the area but are locally dolomitic and siliceous and commonly interleaved with granite and schist.

The only dolomite body of note is an arcuate lens situated just west of the center of sec. 4 (proj.). It crosses a saddle in the main ridge and extends at least 1,000 feet to the north into NW $\frac{1}{4}$ sec. 4. The average thickness may be 50 to 100 feet. At one point, the body consists of white coarse-crystalline dolomite, but it is not known if dolomite is the predominant carbonate. Reserves are undetermined and none of the above-mentioned deposits is developed.

Sugarloaf deposits. Location: NW $\frac{1}{4}$ sec. 36 and S $\frac{1}{2}$ sec. 25, T. 13 S., R. 3 E. (proj.), M.D., 7 miles northeast of Salinas; San Juan Bautista and Salinas 15-minute quadrangles. Ownership: Not determined.

Bowen and Gray (1959, p. 28) have described the deposit on Sugarloaf Peak:

"A broad belt of carbonate rock 600 to 700 feet wide and over a mile long crosses Sugarloaf Peak, in a northeasterly direction. The southwest third of the mass is mainly dolomite but toward the northeast this grades into mixed dolomite-calcite rock. Northeast of the crest of the peak the mass is poorly exposed because of thick brush and soil mantle. Thus far, there has been no commercial utilization of the Sugarloaf Peak rocks.

"The dolomite is grayish-white, mottled with small spots and clots of red iron oxide. Veinlets of iron oxide and ferruginous silica cut the mass in numerous places. Where the carbonate mass is poorly exposed east of the peak, float consists of medium-grained and coarse-grained, blue-gray to white dolomitic limestone and finer-grained off-white dolomite.

"Because of the impure nature of the dolomite on the southwest slope of Sugarloaf Peak and because of the apparent mixture of calcite and dolomite rock east of the peak, it is doubtful if satisfactory commercial deposits can be developed in this vicinity."

Another broad northeasterly-trending belt of carbonate rock is shown by Allen (1946, plate 1) in sec. 36, a short distance southeast of the Sugarloaf Peak belt. Nothing is known about the quality of limestone or dolomite in this large mass, but Allen (1946, p. 67, 72, and plate 2) states that limestone was obtained from a quarry at the top of the hill half a mile south of Sugarloaf Peak. This limestone was reportedly burned in an old brick kiln located at the forks of Gabilan Creek a mile northeast of Sugarloaf Peak. Allen (1946, plate 1) shows several other large masses of carbonate rock $\frac{1}{2}$ to 2 miles southeast of Sugarloaf Peak but does not describe them or differentiate the limestone and dolomite. On the basis of size alone, these deposits would appear to warrant further examination and exploration to assess their economic value.

Underwood deposits. Location: Near center sec. 13 (proj.), T. 13 S., R. 4 E., M.D., 4 $\frac{1}{2}$ miles southeast of San Juan Bautista; Hollister 15-minute quadrangle. Ownership: Ideal Cement Company, 420 Ideal Cement Building, Denver, Colorado 80202 (1959).

This deposit is described by Bowen and Gray (1959, p. 25):

"The Underwood deposits are a series of small, discontinuous masses of limestone located near the San Andreas fault zone close to and on the northeast side of the San Juan Canyon Road half a mile north of the Pearce-Twahy deposit. The Underwood property is part of the former Cienega del Gabilan land grant. It was operated for many years as a source of cement rock by the San Juan Portland Cement Company. The limestone reserves have been largely depleted and the quarries have been long idle.

"The limestone masses are within a triangular area bordered on the north and east by faults and on the west by San Juan Valley alluvium. The total reserves probably never exceeded a million tons, and individual masses ranged from a few thousand tons to several hundred thousand tons. The masses are in granite and quartz-microschist wall rocks. The rock is similar in character to that of the Bryan and Pearce-Twahy deposits."

Other references: Bradley and Logan, 1919, p. 628; Logan, 1947, p. 276; Taliaferro, 1948 (map).

Upper Bird Creek deposit. Location: NE $\frac{1}{4}$ sec. 6 (projected), T. 14 S., R. 5 E., M.D., 7 $\frac{1}{2}$ miles southwest of Hollister; Hollister and Gonzales 15-minute quadrangles. Ownership: Dr. Rollin Reeves, Salinas; mineral rights probably held by Ideal Cement Company (1959).

This limestone deposit is described by Bowen and Gray (1959, p. 32):

"In plan this deposit is shaped like a T-bone steak with the longest axis trending northwest. It is about 1,600 feet long, 800 feet in maximum width, and has been exposed to a depth of over 400 feet. Most of the rock is medium-grained, blue-gray material suitable for portland cement, but a dolomite streak crosses the northwest end of the mass and the deposit would have to be thoroughly tested by drilling to establish whether the mass as a whole is sufficiently low in magnesium. Five to 10 million tons of limestone could probably be developed in the Upper Bird Creek deposit. The following analyses done by I.A. Caetano, courtesy Ideal Cement, on type samples collected by Gray are representative of most of the deposit:"

Sam- ple	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	Ign. loss
G-16..	0.38%	0.12%	0.18%	55.4%	0.35%	0.03%	0.10%	43.65%
G-17..	0.50	0.12	0.12	54.8	0.54	0.03	0.04	43.68
G-18..	0.88	0.08	0.10	50.2	4.38	0.03	0.05	44.18
G-19..	1.28	0.11	0.13	54.0	0.39	0.05	0.13	43.34
G-20..	0.98	0.15	0.17	54.2	0.35	0.05	0.05	43.26

There is no known development of the deposit.

Westphal Ranch deposit. Location: Secs. 10 and 11, T. 15 S., R. 5 E., M.D., on the south slope of Mt. Olds, 8 miles northeast of Chualar; Gonzales 15-minute quadrangle. Ownership: Herald Ranch (a trust estate), Herb G. Meyer, 145 Auburn Street, Salinas (1959).

The general distribution of carbonate rock of the Westphal Ranch deposit is shown in plate 2. The deposit is described by Bowen and Gray (1959, p. 38-39):

"The beds are sinuous but have a general east strike and a steep south dip. The carbonate rocks are interbedded with quartz-microschist and quartzite, and some skarn-rock has developed along granitic contacts. None of the lenses exceed 200 feet in width and they are scattered along more than a mile of strike length. The rock

is medium- to coarse-crystalline and blue-gray to nearly white. The chemical variations, based upon nearly 100 surface samples, are indicated in the following table:

Fe	SiO ₂	Al ₂ O ₃	CaO	MgO	S	P	Mn	R ₂ O ₃	CO ₂ and	
									H ₂ O	
15.30	28.52	07.65	32.933.8	2.0-18.2	01-.005	.001-.13	.02-.06	54.93	42-44	

"Because of the heterogeneous nature of the deposit uniform rock can only be obtained in masses containing less than 1,000,000 tons each; many are much smaller than this."

Other carbonate deposits exist to the west in sections 9 and 10, but nothing is known of them. These and the Westphal Ranch deposit are undeveloped.

Westvaco (Hollister; O'Hara Ranch) deposit. Location: Sec. 2 (proj.), T. 15 S., R. 5 E., M.D., 7 miles south of Hollister; Gonzales 15-minute quadrangle. Ownership: Inorganic Chemicals Division, FMC Corporation, P.O. Box 344, Newark (1963).

Crystalline dolomite, exposed on a low hill half a mile south of the winery in Cienega Road, has been quarried extensively since 1915. In that year, two companies opened quarries within half a mile of one another. San Benito Quarries Company (Baldi and Rothschild) developed a quarry and adit near the top of the hill on the O'Hara Ranch and produced modest amounts of dolomite until 1926. About half a mile to the west, on the property of San Benito Vineyards Company, and near the center of sec. 20, A. A. Haskins opened a hillside quarry which he apparently worked in a limited way for a few years. From 1937 to 1946, A. E. Hamilton produced an average of 7,000 or 8,000 tons of dolomite annually from the same area as Haskins. This part of the deposit may still be owned by Mrs. A. E. Hamilton. Hamilton also had an option on the O'Hara Ranch property, which he explored to some extent.

In April 1944, Westvaco Chlorine Products Corporation (predecessor of present owner) acquired that option and has produced substantial amounts of dolomite every year since 1947. Practically all of the dolomite produced prior to 1947 was shipped to San Francisco and Los Angeles for use as a refractory lining in open hearth steel furnaces. All of the dolomite produced from 1947 to 1968 was shipped to the owner's chemical plant in Newark where the dolomite was calcined and reacted with salt water bitterns to produce magnesium compounds. The Newark plant ceased operation in August 1968. Quarry operations were either stopped or greatly reduced by the end of 1968, although some dolomite fines were being sold for agricultural use and glass manufacturing. Total production of dolomite from 1915 to 1968 is estimated to be about 2½ million tons.

According to previous descriptions and unpublished mapping, the Westvaco deposit apparently is half a mile long but may consist of several disconnected masses of dolomite mostly in SE¼ sec. 2. The main part of the deposit has been examined and described

by Bowen and Gray (1959, p. 37):

"White, medium crystalline dolomite occurs in a northwest-elongated mass roughly oval in plan. The mass is at least 1,800 feet long and 600 feet wide and has been explored to a depth of nearly 200 feet. It is enveloped in deeply weathered schist and granitic rock and granitic intrusions penetrate the dolomite in several places. The deposit is in or close to the San Andreas fault zone and the dolomite has been thoroughly crushed throughout the deposit. This lowers the cost of quarrying but raises the proportion of waste material. Several million tons of usable rock were proved. Further exploration was being done during the summer of 1958. According to the company the rock runs close to the theoretical composition for dolomite—slightly over 21 percent MgO. Iron oxide stains along the fracture surfaces are the only visible impurity. Lagan (1947, p. 278) lists an analysis made by Smith-Emery Company from a sample collected toward the north end of the mass from a quarry then operated by A. E. Hamilton, which is probably representative of the deposit."

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Mn	CO ₂
0.17%	0.36%	0.11%	31.00%	21.23%	0.006%	47.30%

Other references: Bradley and Lagan, 1919, p. 633-635; Averill, 1947, p. 49-50.

PANOCHÉ HILLS DISTRICT (C-2)

Marly magnesian limestone is found as lake beds in the Tulare Formation of Plio-Pleistocene age in several places in the Panoche Hills, Fresno County (plate 1C). The carbonate rock, known as the Marlite deposit, was produced in the vicinity of sec. 18, T. 14 S., R. 11 E., between 1947 and 1953 for use in soil conditioning. The material is considered too impure to be of value for most limestone or dolomite uses.

Marlite (Burkhart and Teaford) deposit. Location: Secs. 17, 18, 19, 20, 29, 30, T. 14 S., R. 11 E., M.D., 2½ miles east of Mercy Hot Springs and 24 miles west of Mendota; Panoche Valley 15-minute quadrangle. Ownership: A. R. Burkhart and Otis Teaford (1951); operated by Marlite Company, Fresno, J. H. McCloy, Jr., President (1953).

The Marlite marl deposit was first developed in 1946 by A. R. Burkhart and Otis Teaford, who located 15 placer claims at the crest of the Panoche Hills. Commercial development followed in 1947 when the Marlite Company, apparently under a lease from the owners, commenced production that continued at least until 1953. There was a little production in 1955, apparently all experimental.

The marl (impure limestone), exposed along the crest of the Panoche Hills in secs. 17, 18, 19, 20, 29 and 30, occurs as a capping and as thin strata interbedded with clay, silt, and sand of the flat-lying, nonmarine Tulare Formation (Plio-Pleistocene). Some of the limestone resembles caliche, but most of it was probably formed as lake beds. Where quarried at the hill crest in sec. 18, the limy bed is estimated to be 3 to 5 feet thick and is covered by 1 to 4 feet of soil. The limestone is nearly white to light buff, porous, soft to moderately hard, and breaks or crumbles easily into small fragments. As indicated by the analyses in table 15, the material is quite impure, being siliceous, alumi-

nous, and dolomitic. Similar limestone occurs to the southeast in SE $\frac{1}{4}$ sec. 18 and NE $\frac{1}{4}$ sec. 19, along the crest of the Panoche Hills. Impure limestone and other marly beds of the Tulare Formation also are reported in Little Panoche Valley and elsewhere to the north (Briggs, 1953, p. 48-49) and in N $\frac{1}{2}$ sec. 30 to the south (Anderson and Pack, 1915, p. 210). Analyses of limestone from sec. 30 are given in table 15.

Table 15. Chemical analyses of limestone of the Tulare Formation, Panoche Hills, Fresno County.

Oxide	Samples from sec. 18 *		Samples from sec. 30 **	
	Marlife 1	Marlife 2	#1	#2
SiO ₂	12.30%	14.30%	19.84%	9.74%
Al ₂ O ₃	8.20	5.30	4.97	2.76
Fe ₂ O ₃	1.30	0.80	1.95	1.65
MgO	8.80	16.00	5.28	1.85
CaO	32.90	25.30	34.06	45.48
Na ₂ O	0.50	0.30	ND	ND
K ₂ O	0.30	0.20	ND	ND
P ₂ O ₅	0.05	0.03	ND	ND
SO ₃	ND	ND	none	none
Ignition loss (CO ₂ +H ₂ O)	34.20	37.50	29.85	35.94
Total	98.55	99.73	95.95	97.42

ND= Not done.

* Samples Marlife 1 and 2 were collected by Earl W. Hart and analyzed by Lydia Lofgren, Division of Mines and Geology, March 1963. Marlife 1 is soft, crumbly, represents 2 feet of thickness near center 18-14S-11E; Marlife 2 is from moderately hard, thin ledge in NW $\frac{1}{4}$ 18-14S-11E.

** Anderson and Pack (1915, p. 210) samples are from N $\frac{1}{2}$ 30-14S-11E. Sample #1 is typical of marl bed 15-20 feet thick; #2 is from thin, hard limestone bed (analyst, George Steiger).

Development of the Marlife deposit consists of several shallow pits or broad trenches from which material was quarried in NW $\frac{1}{4}$ and center of sec. 18. A few prospect pits and trenches are located within 2 miles to the southeast along the crest of the hills. Quarrying of the thin marl horizon and removal of overburden were conducted using a tractor-powered carryall. The marl was delivered to a nearby hammer mill, where it was pulverized, and subsequently delivered to points in the San Joaquin Valley for sale as agricultural limestone (Logan, et al., 1951, p. 507-508). The production pits have estimated maximum dimensions of 400 feet long, 100 feet or more wide, and 5 to 10 feet deep. It is estimated that roughly 30,000 to 40,000 tons of marl and soil overburden were excavated. Probably over half of this was processed as agricultural lime. According to the California Department of Agriculture (Special Publications 231, 236, 239, 244, 247, 251), partial analyses of the commercial marl varied from 33.75% to 48.47% CaCO₃ during the 1948-1953 period. Apparently some soil was admixed with the marl during excavation, as these analyses are lower in equivalent CaO than sample analyses shown in table 15. Future value of the Marlife deposit and similar marl deposits of Panoche Hills appears to be limited to agricultural uses. There is no record of commercial production since about 1953.

NORTHERN SANTA LUCIA DISTRICT (C-3)

This district encompasses the northern half of the Santa Lucia Range and the smaller Sierra de Salinas to the northeast. It lies totally within Monterey County (plate 1C). Much of the northern Santa Lucia Range district is rugged and rather remotely situated with respect to major lines of transportation. The northeast side of the district is served by a railroad and highway along the Salinas Valley. The southwest side, where most deposits are located, is served only by a winding highway along the precipitous Pacific Coast. The nearest major marketing center is the San Francisco Bay Area 100 to 150 miles to the north.

The oldest and most important carbonate deposits are crystalline limestone and dolomite associated with schist, gneiss, quartzite, and other metamorphic rocks of the pre-Cretaceous Sur Series. This metamorphic unit has been intruded by granitic rocks of probable Late Cretaceous age. Upper Cretaceous, Tertiary, and Quaternary sedimentary rocks flank and locally overlie the crystalline basement. Except for impure dolomite of the Miocene Monterey Formation and an unidentified shell deposit, none of the sedimentary rocks has been of economic interest. No limestone or dolomite deposits are known from the Franciscan rocks southwest of the Sur-Nacimiento fault zone. Uplift and erosion in recent geologic time have exposed the crystalline basement rocks over a broad region in the northern part of the range. Faulting and folding have severely deformed the range, and the older crystalline rocks in particular are brecciated and sheared in many places.

The great bulk of carbonate rock in the northern Santa Lucia Range is confined to a 3-mile wide, northwest-trending belt in the Coast Ridge area (Hart, 1966b, p. 61-62). The belt is more or less defined by the Sur-McWay (Nacimiento) fault zone on the southwest and the Palo-Colorado and Coast Ridge faults on the northeast (Jennings and Strand, 1958). Carbonate rocks also are found west of Junipero Serra Peak and elsewhere in the range but in much smaller concentrations. The general distribution and locations of the known carbonate deposits, based largely on the work of Trask (1926), Reiche (1937), and Fiedler (1944), are shown in figure 5. Most of the deposits are much smaller than indicated and generally consist of multiple small lenses and beds of carbonate rock associated with various noncarbonate rock.

Although a few deposits are relatively pure limestone, most carbonate bodies are mixtures of limestone and dolomite, the former predominating. Much of the Sur Series limestone is white to light blue gray and fine to very coarse crystalline, with local concentrations of graphite crystals 1 or 2 mm across. Near intrusive contacts, the limestone shows development of a wide variety of calcium and magnesium silicates. Silica also is present as quartz. Dolomite occurs both

Figure 5. Map showing distribution of Sur Series carbonate rocks, northern Santa Lucia Range.

as an impurity interspersed with calcite and as relatively pure bands and zones that replace the limestone. The purer types of dolomite are fine to coarse crystalline, off white to gray and cream colored.

There have been no commercial developments of carbonate rock for many years in the northern Santa Lucia Range. Limestone at Bixby Creek and Limekiln Creek (near Lucia) was burned for lime and exported from Monterey County by ocean vessels prior to 1910. Deposits at Tassajara Hot Springs, Lambert Ranch, Limekiln Creek (near Chualar), and Jolon, however, were developed only as small, local sources of lime rock.

Pico Blanco is the outstanding deposit in the region, containing immense reserves of limestone of adequate quality to meet the specifications of cement and other limestone uses. Deposits at Bixby Mountain and Limekiln Creek (near Lucia) probably contain substantial limestone reserves, but the limestone is of variable quality and is distributed among numerous small to medium-sized bodies. The Horse Canyon deposit also may contain substantial reserves, but requires closer examination before it can be evaluated. Smaller reserves of limestone, and possibly dolomite, are available at other deposits. Future development of the various deposits is hindered by poor accessibility and distance from transportation and market facilities. Additionally, some interests would no doubt oppose any mining operation that might impair the recreational and wilderness values of the region. Nonetheless, development of the Pico Blanco limestone and possibly other deposits undoubtedly will be desirable in the future.

The deposits are described alphabetically below.

Bixby Creek deposit. Location: N $\frac{1}{2}$ sec. 16 and S $\frac{1}{2}$ sec. 9, T. 18 S., R. 1 E., M.D., 16 miles south of Monterey and 2 miles east of Bixby Landing; Point Sur 15-minute quadrangle. Ownership: Not determined.

This deposit was worked from 1904 to 1910 by Monterey Lime Company of San Francisco (Logan, 1947, p. 259). During this period, an estimated 75,000 tons of limestone were produced and calcined in three large vertical wood-fired kilns situated on Bixby Creek (Aubury, 1906, p. 73). The lime was hauled by overhead tramway to Bixby Landing on the coast where it was loaded onto ships waiting off shore. There were no roads into the area at the time of development, although a dirt road now extends to the deposit from the coast.

Small detached masses of limestone centering near N $\frac{1}{4}$ cor. sec. 16 extend northwestward over a distance of half a mile and constitute the Bixby Creek deposit. The masses of limestone are locally brecciated and cut by numerous salients of granitic rock. The limestone mainly is white and coarse crystalline and often contains concentrations of graphite crystals. Analyses of three samples of the better quality limestone from the quarry area (Hart, 1966b, p. 62) are given below (in

percent by weight):

Sample	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	P ₂ O ₅
LSL-5.....	3.84%	0.10%	0.18%	51.82%	1.04%	0.02%
LSL-6.....	1.82	0.08	0.38	52.80	1.22	0.03
LSL-7.....	1.96	0.12	0.30	52.93	1.06	0.03

Development of the deposit consists of a series of small quarries or pits situated near N $\frac{1}{4}$ cor. sec. 16 about 1,000 feet north of the lime kilns. Future development of the Bixby Creek deposit is limited by its small size and remote location.

Bixby Mountain deposits. Location: Mainly W $\frac{1}{2}$ sec. 14, secs. 15 and 23, and N $\frac{1}{2}$ sec. 25, T. 18 S., R. 1 E., M.D., 16 to 18 miles south of Monterey and 3 to 4 miles inland from the coast; Point Sur 15-minute quadrangle. Ownership: Not determined.

The Bixby Mountain deposits comprise a group of carbonate bodies that extend southeastward for a distance of 3 miles from Bixby Creek near the north border of sec. 15 to Little Sur River in N $\frac{1}{2}$ sec. 25. Situated in rugged, heavily vegetated terrain, the deposits range in elevation from 800 feet at Bixby Creek to 2,920 feet at Bixby Mountain. Trask (1926, p. 131, map) depicted the crystalline carbonate rocks as northeast-dipping, elongated bodies lying at three or four principal horizons within the Sur Series. The largest body, located mostly in SW $\frac{1}{4}$ sec. 14, is indicated by Trask to cover an area 2,000 feet wide and more than a mile long. Based on a partial, brief examination of sec. 23 and 24 by Oliver E. Bowen (oral communication, 1961 and 1964), the carbonate bodies of Trask are composite, consisting of smaller bodies of carbonate rock associated with schist and other metamorphic rocks of the Sur Series. Most of the deposits are mixtures of limestone and some dolomite and are commonly cut by fingers of granitic rock. The limestone and dolomite are similar to other carbonate rocks in the northern Santa Lucia Range, varying from white to gray and from fine to very coarse crystalline. Chemical analyses of typically white, medium- to coarse-crystalline, good-quality limestone from the main mass north of Bixby Mountain are given in percent by weight by M. E. Maddock and C. C. Carlson (1961, unpublished consulting report for O. P. Jenkins):

Sample	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	P ₂ O ₅
B-1.....	1.32%	0.02%	0.78%	54.09%	0.54%	0.12%
B-2.....	1.04	0.03	0.53	54.19	0.68	0.09

It is possible that small to moderate-sized deposits of limestone or dolomite of economic interest may exist in the Bixby Mountain area, although insufficient work has been done to delineate specific bodies. However, preliminary examination does indicate no large reserve at any one deposit. Future development of the deposit will undoubtedly be hampered by the remoteness and difficult access of the region.

Other reference: Hart, 1966b, p. 62-63.

Coast Ridge deposits (includes Marble Peak). Location: T. 19 and 20 S., R. 2 E., T. 20 S., R. 3 E., and T. 21 S., R. 3 and 4 E., M.D., 24 to 42 miles southeast of Monterey; Lucia 15-minute quadrangle. Ownership: Not determined, but partly Los Padres National Forest (1960).

A large number of small to medium-sized bodies of Sur Series carbonate rock occur discontinuously along an 18-mile northwest-trending belt (figure 5). These lie between the Coast Ridge fault and the McWay fault and are described in a general way by Reiche (1937, p. 123–126, 193, map). The deposits of the northwest half of this belt, which are exposed intermittently along the Coast Ridge road, were examined briefly in 1960 and found to be too small and impure to be of economic interest (Hart, 1966b, p. 130–131). Most of these carbonate bodies showed significant amounts of silicate minerals due to contact metamorphism. The deposits examined include some of the small undeveloped deposits reported in the vicinity of Marble Peak (SW $\frac{1}{4}$ sec. 22, T. 20 S., R. 3 E.) by Logan (1947, p. 259).

The deposits southeast of Marble Peak were not visited.

Horse Canyon deposit. Location: S $\frac{1}{4}$ sec. 35, T. 19 S., R. 5 E., and N $\frac{1}{2}$ sec. 2 and NE $\frac{1}{4}$ sec. 3, T. 20 S., R. 5 E., M.D., 11 miles southwest of Greenfield; Junipero Serra 15-minute quadrangle. Ownership: mainly Los Padres National Forest (1968).

According to D. L. Durham (1968, personal communication), pre-Tertiary crystalline limestone is well exposed along Horse Canyon in secs. 35 and 3 and on the high ridge to the east in sec. 2. The limestone is associated with other metamorphic rocks of the Sur Series that form a northwest-trending fault block bounded by Mioocene sandstone and calcareous shales on the northeast and Eocene sandstone resting on pre-Tertiary crystalline rocks (undifferentiated) on the southwest. The limestone apparently crops out in an elliptical area roughly a mile long by a third of a mile wide and has a relief of about 1,200 feet on the ridge east of Horse Canyon.

Just how much of the deposit area is underlain by limestone, and the relationship of the limestone to associated Sur Series rocks, remain to be determined. Much of the limestone is reported to be white. A small sample provided by Durham consists almost entirely of coarse-crystalline calcite with scattered flakes of graphite and small grains of iron ore (limonite?). It is not known if the sample is representative of the deposit.

Preliminary data justify a closer look at this deposit to determine its size, distribution, relationship to other Sur Series rocks and possible granitic intrusives, and chemical variations. Should a large limestone deposit—or even modest reserves of high-quality limestone—prove to exist, its economic value would be enhanced by its relative accessibility to major trans-

portation lines and favorable topographic relief. Oliver E. Bowen (personal communication, 1970) estimates reserves of carbonate rock to be roughly 10 to 15 million tons.

Jolon deposit. Location: Not determined. Ownership: Not determined.

A “shell deposit” a few miles south of Jolon, Monterey County, reportedly supplied material for a lime kiln operated prior to 1893.

References: Preston, 1893, p. 260; Logan, 1947, p. 259.

Junipero Serra deposits. Location: Sec. 6, T. 21 S., R. 5 E., and secs. 13, 24, and 36, T. 20 S., R. 4 E., M.D., 19 to 20 miles west of King City; Junipero Serra 15-minute quadrangle. Ownership: U.S. Government; claimed by Sparks, Pearson, and Talcott in sec. 6 and by Frank Watkins in SW $\frac{1}{4}$ sec. 36 (1958–1959).

A number of Sur Series carbonate bodies of undetermined size lie 3 to 5 miles from Junipero Serra Peak within half a mile of Indians Road. They are situated in rugged terrain that is accessible over many miles of improved dirt and paved roads from King City and Greenfield. The deposits are undeveloped except for claim location work and minor sampling.

Perhaps the largest deposit lies in the SE $\frac{1}{4}$ sec. 6 on the Sparks, Pearson, and Talcott claims. Exposures of limestone just north of Roosevelt Creek show the deposit to be 150 to 200 feet thick and to dip steeply into the hill. Exposures of carbonate rock can be traced visually to the northwest along a common trend, but it is not known if they represent a contiguous deposit or multiple lenses. At the southeast end of the trend, the deposit largely consists of very coarse-crystalline, nearly white limestone containing local concentrations of crystalline graphite and possibly some silica (Hart, 1966b, p. 66). An analysis of SP-1, a typical example, is given in table 16. Samples SP-2 and 3 are siliceous dolomite of the Mioocene Monterey Formation exposed southwest of the limestone in sec. 6.

A mile or more northwest of the above claims and along the same deposit trend are the claims of Frank Watkins in SW $\frac{1}{4}$ sec. 36. Here, the carbonate rock is impure and not well exposed. Chemical analysis of two samples (Jun-1 and 2 in table 16) indicate the material to be siliceous and strongly dolomitic. Five other samples (Indians 1–5), taken from bodies 50 feet thick or less, show that relatively pure limestone and dolomite are present along Indians Road. Other carbonate bodies are indicated a short distance west of the road by Reiche (1937, map), but have not been examined.

The carbonate deposits examined appear to be of limited economic interest at the present time because of their small size, variable quality, and remote locations with respect to markets. However, more work needs to be done to evaluate the Junipero Serra deposits. The nearest rail facilities are 30 to 35 miles away by road.

Table 16. Chemical analyses of carbonate rock samples from Junipero Serro deposits, Monterey County.

Sample	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	P ₂ O ₅	Ign. loss
SP-1	1.08%	0.16%	0.34%	53.50%	1.12%	0.10%	ND
SP-2	24.00	1.00	0.44	23.12	15.52	0.05	ND
SP-3	9.32	0.30	0.43	29.06	17.91	0.18	ND
Jun-1	3.88	0.13	0.53	34.31	16.26	0.02	ND
Jun-2	7.70	0.17	1.62	37.77	10.10	7.11	ND
Indians 1 ..	2.65	0.41	0.31	54.25	0.51	0.08	41.80%
Indians 2 ..	3.65	0.27	0.33	53.75	0.68	0.1	41.24
Indians 3 ..	0.61	0.14	0.08	55.00	0.51	0.08	43.44
Indians 4 ..	1.64	0.04	0.08	52.75	2.04	0.1	42.60
Indians 5 ..	0.13	0.07	0.04	33.25	19.50	0.02	46.72

ND not done.

SP samples collected in SE $\frac{1}{4}$ 6-21S-5E by Oliver E. Bowen and Earl W. Hart, July 18, 1957, and analyzed by Abbot A. Hanks, Inc., March 25, 1958. SP-1 is Sur Series crystalline limestone; SP-2 and -3 are pale brown, siliceous dolomite of the Monterey Formation.

Jun samples collected in SW $\frac{1}{4}$ 36-20S-5E by Frank Watkins in 1957 and analyzed by Abbot A. Hanks, Inc., March 26, 1958. Samples are from Sur Series.

The Indians samples were collected by Oliver E. Bowen, April 30, 1959, and analyzed by Lydia Lofgren of the Division of Mines and Geology, October 26, 1962. The samples are from small lenses of Sur Series exposed along Indian Road in SW $\frac{1}{4}$ sec. 13, NW $\frac{1}{4}$ sec. 24, and SW $\frac{1}{4}$ sec. 36, T. 20 S., R. 5 E.

Lambert Ranch (Jamesburg) deposit. Location: SW $\frac{1}{4}$ sec. 17, SE $\frac{1}{4}$ sec. 18, and NW $\frac{1}{4}$ sec. 20, T. 18 S., R. 4 E., 24 miles southeast of Monterey and $1\frac{1}{2}$ miles southeast of Jamesburg; Jamesburg 15-minute quadrangle. Ownership: Not determined.

The deposit consists of several small limestone lenses which were mapped by Fiedler (1944, p. 183, plate 9) as a single lens half a mile long, trending N 20° W and centering just east of the SW cor. sec. 17. The limestone is described by Oliver E. Bowen (Hart, 1966b, p. 66-67) as medium to coarse crystalline, white to light blue gray, and cut by numerous fingers of granitic rock. It is developed by two small quarries, long abandoned. Because the deposit locally contains silicate minerals and is small, it probably is not of commercial interest. Bowen collected three samples of limestone in 1954 and had them analyzed by Abbot A. Hanks, Inc. The first two are from the north quarry and the third from the south quarry.

Sample	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	P ₂ O ₅
LSL-2	0.24%	0.09%	0.13%	54.38%	0.99%	Tr
LSL-3	0.18	0.08	0.12	54.29	1.12	Tr
LSL-4	0.16	0.11	0.13	54.39	1.06	Tr

The limestone probably was quarried as a source of lime, but there is no record of production.

Limekiln Creek deposit (near Chualar). Location: E $\frac{1}{2}$ sec. 28, T. 16 S., R. 4 E., M.D., 4 miles south of Chualar; Salinas 15-minute quadrangle. Ownership: Not determined.

Two small lenses of Sur Series limestone, located just north of the canyon mouth of Limekiln Creek, were developed by tiny quarries many years ago. The rock was calcined for lime at a nearby kiln. The limestone is white, medium to coarse crystalline, and local-

ly graphitic. The main or northeast lens is a little over 100 feet long and is a northwest-trending pendant in granitic rock (Oliver E. Bowen, 1960, personal communication). Two limestone samples, one from each lens, were collected by Bowen and analyzed by Abbot A. Hanks, Inc., in 1955 (Hart, 1966b, p. 67).

Sample	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	P ₂ O ₅
LSL-8	0.32%	0.09%	0.21%	53.53%	1.66%	0.03%
LSL-9	0.54	0.06	0.30	52.81	2.07	0.02

Production is believed to total 1,000 tons or less. The limestone lenses apparently are too small to be of economic interest. Several other carbonate masses are indicated to the northwest in secs. 8, 13, and 14, T. 16 S., R. 3 E., and secs. 18, 19, and 21, T. 16 S., R. 2 E. by C. L. Herold (1935, unpublished thesis); but these are probably small and inaccessible. They have not been examined. Two additional deposits of crystalline limestone are reported by Oliver E. Bowen (1968, oral communication) to underlie several acres of SW $\frac{1}{4}$ sec. 9, T. 16 S., R. 3 E. at the head of San Benancio Canyon.

Limekiln Creek deposits (near Lucia). Location: Sec. 10, SW $\frac{1}{4}$ sec. 11, NW $\frac{1}{4}$ sec. 14, and sec. 15, T. 22 S., R. 4 E., M.D., 1 to 2 miles east of Lucia; Lucia, Junipero Serra, and Cape San Martin 15-minute quadrangles. Ownership: S. H. Cowell Foundation, 25 California Street, San Francisco, and U.S. Government (1964).

Numerous small to moderate-sized deposits of carbonate rock are reported between the main and west forks of Limekiln Creek. These are interbedded with schist of the Sur Series and are commonly cut by dikes of light and dark granitic rocks. Because carbonate rock talus is so prevalent in secs. 10 and 15, the impression is given that an immense carbonate body exists (see Reiche, 1937, p. 163 and map). However, Oliver E. Bowen (1964, personal communication) reports that the largest body present in this area is a northeast-dipping rib of carbonate rock averaging perhaps 100 to 150 feet thick. The rib is situated near the S $\frac{1}{4}$ cor. sec. 10 and is best exposed on the west side of the main spur south of "hill 2449". The deposit is a complex mixture of massive, white, coarse-crystalline to platy, gray, banded, fine-crystalline limestone. Some of the limestone is dolomitic (cream-colored dolomite), and much is siliceous. The carbonate rocks have been contact-metamorphosed, forming various magnesium, calcium, and aluminum silicates; and commonly they have been brecciated and recemented. According to Bowen, other impure carbonate masses are found in the vicinity, but most are small and none is of sufficient quality to be of significant economic interest. Chemical analyses of samples from the prominent carbonate lens exposed near "hill 2449" in S $\frac{1}{2}$ sec. 10 are presented below. Analyses were made in 1964 by Matti Tavela and Lydia Lofgren of the Division of Mines and Geology. The samples are typical of the limestone and dolomitic and probably represent the great bulk of the deposit.

Sample	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	P ₂ O ₅	Ign. loss
LC-1	5.50%	0.13%	0.20%	51.50%	1.20%	0.01%	41.90%
LC-2	1.30	0.15	0.00	54.00	1.30	0.04	42.60
LC-3	1.40	0.32	0.42	34.80	17.20	0.01	45.20

The above carbonate deposits apparently extend discontinuously 6 miles to the southeast to the west flank of Chalk Peak in S½ sec. 28, T. 22 S., R. 5 E. (figure 5). Near the middle of the carbonate belt, where it crosses the connecting road between the coast and Jolon, the limestone masses are too thin and impure to be of commercial interest. Deposits farther to the southeast near Chalk Peak, indicated by Jennings (1958), have not been examined.

The only limestone development in the vicinity took place during the 1880s by the Rockland Lime and Lumber Company, which erected four vertical kilns along the West Fork of Limekiln Creek (SW¼ sec. 15, T. 22 S., R. 4 E.). Crushed and broken limestone from a large landslide situated on the steep slope northeast of the kilns was utilized. The company developed several shallow hillside pits in the crushed limestone and sledged the material down slope to the kilns. The kilns, each of which had a capacity of 110 barrels of lime per day, apparently were loaded overhead and fired by wood. Lime was hauled to Rocklands Landing about a mile away and loaded by aerial tramway aboard waiting ships. Around 1890, the property was acquired and shut down by Henry Cowell Lime and Cement Company. It has been inactive since that time.

The quarry vicinity was examined briefly by this writer in August 1959. Although good limestone undoubtedly was selected from the landslide debris for calcining, not all of the limestone is of good quality. Locally, the limestone is dolomitic and associated with metamorphic and granitic rock much like the main deposit higher on the spur. Some of the rocks appear to be in place and either represent Sur Series beds underlying a thin veneer of landslide debris or are portions of a large, partly crushed block that slid downslope from the main limestone mass. It is not likely that further commercial development will take place in this landslide area.

Other references: Irelan, 1888, p. 410; Crawford, 1894, p. 392; Crawford, 1896, p. 629; Aubury, 1906, p. 72; Logan, 1947, p. 259; Hart, 1966 b, p. 63.

Pacific Carrara Marble Company. A company by this name was organized prior to 1880 to develop a deposit of white limestone near Carmel Bay. There is no record of production, but a small deposit of Sur Series limestone near Big Sur is reported (unverified) to be developed by a small, old quarry.

References: Hanks, 1884, p. 110; Logan, 1947, p. 260.

Pico Blanco deposit. Location: Secs. 25 and 36, T. 18 S., and secs. 1, 2, 11, and 12, T. 19 S., R. 1 E., M.D., 20 miles south of Monterey and 2 to 3 miles northeast of State Highway 1; Big Sur 7½-minute quadrangle.

Ownership: Granite Rock Company, P. O. Box 151, Watsonville, owns sec. 36 and controls adjacent unpatented mining claims (1964).

The Pico Blanco deposit is probably the largest mass of good quality, uniform grade limestone within 150 miles of San Francisco. Although reserves appear to be enormous, the deposit has never been developed commercially because of its relatively inaccessible location and distance from major sources of transportation.

Formerly, sec. 36 of the deposit was owned by Mrs. C. L. Koch. This section was acquired about 1956 by Tom Maher who also located claims in the vicinity. Maher's holdings were obtained in the late 1950s by Olaf P. Jenkins of Pacific Grove. Jenkins had the deposit sampled and mapped in detail by M. E. Maddock (1960, unpublished report) and M. E. Maddock and C. C. Carlson (1961, unpublished report). Results of these surveys are summarized by Hart (1966b, p. 63-66) and are largely repeated here. Granite Rock Company acquired the Pico Blanco property about 1963 after leasing it for a short period of time.

The name Pico Blanco means "White Peak" in Spanish and refers to the white limestone which caps the summit and east and south flanks of the 3,709-foot peak. The deposit, previously accessible only by foot trails from the Old Coast Road and the Pico Blanco Boy Scout Camp, can now be reached by jeep road, completed in 1964, from the coast via Dani Ridge.

The deposit contains two bodies of crystalline limestone of economic interest—known as the Pico Blanco body and the Hayfield body—and numerous smaller bodies of little commercial importance. The Pico Blanco body is a thick, tabular mass exposed over an irregular area measuring 2½ miles from north to south (figure 6). The northern part of the body dips 35° to 55° NE and appears to be a homocline; but the southern third is structurally complex, probably being a faulted, southeastward plunging anticline. Southwest of the Pico Blanco body is the Hayfield body located in SE¼ sec. 1. This mass of crystalline limestone blankets the south slope of the peak and probably has a maximum thickness of 100 to 200 feet.

In large part, the Pico Blanco and Hayfield bodies consist of white or nearly white, coarse-crystalline limestone composed almost entirely of calcite, with minor amounts of quartz and graphite. Local concentrations of granular quartz in thin resistant bands exist, but they are quantitatively unimportant. Dolomite also is found in some places as alternating bands or disseminated crystals in the limestone. In one place along the South Fork of the Little Sur River, banded dolomite constitutes a horizon 40 to 50 feet thick. Phlogopite (magnesium mica) in small "trains" and other magnesium silicate minerals occur locally. The dolomite, quartz, and silicate minerals present would be considered impurities in most limestone uses, although minor occurrences of these contaminants may be diluted by quarrying with high-quality limestone.

Figure 6. Geologic map of Pico Blanco limestone deposit, Monterey County.

Larger masses of impurities, which are not too common, generally can be avoided by selective mining. If the limestone is used for cement, a high silica content actually may be desirable. Other contaminating materials associated with the limestone are schist and

gneiss interbeds and granitic dikes. These rocks usually are restricted to the marginal parts of the limestone bodies and may not present serious mining problems.

Through early 1961, development of the Pico Blanco deposit had been restricted to sampling and geologic mapping. A few test pits have been developed on the claims as a part of the assessment work and, since 1961, limited core drilling has been done, but drill data are not available.

Prior to 1961, samples from 44 localities (figure 6) were analyzed for chemical composition (table 17). Although an insufficient number of samples was analyzed to delineate areas of various quality limestone, sampling and field inspection indicate that the great bulk of the Pico Blanco and Hayfield bodies consists of good quality limestone that averages about 54 percent lime. It is apparent that the limestone is of sufficiently high quality for cement. Moreover, analyses suggest that some of the limestone is adequate for most lime, chemical, and metallurgical uses.

Reserves cannot be estimated accurately because exact thicknesses of the bodies are not known. However, if it is assumed that the Pico Blanco body has an average thickness of 500 feet, maximum limestone reserves north of the South Fork of the Little Sur River and above 1,600 feet elevation are estimated to be in the order of 600 million tons. Although parts of the deposit are thinner than 500 feet, a maximum thickness of over 1,500 feet is estimated by Marshall E. Maddock (1960, unpublished report for Olaf P. Jenkins), and the reserve estimate is probably conservative. On the other hand, reserves could be reduced significantly depending on the quality and uniformity of limestone required for a particular use, the amount of selective mining necessary, and the amount of deleterious materials associated with the limestone. The maximum reserves of the Hayfield body north of the river are estimated to be about 20 million tons, assuming an average thickness of 100 feet.

By any standard, the Pico Blanco body is enormous and obviously of strong economic potential. The most serious drawback to its development is its relatively remote location, especially with reference to markets or established major transportation lines. Its location in an area of potentially high recreational and wilderness value may also present some development problems. The owners are reported to be exploring the feasibility of various alternative methods of extraction and transportation that would permit development with minimal impact on other values.

Other references: Trask, 1926, p. 131, map; Lagon, 1947, p. 260.

Sierra (Serra) Hill-Little Sur deposits. S $\frac{1}{2}$ T. 18 S., R. 1 E., M.D., extending from the NW $\frac{1}{4}$ sec. 19 southeastward to the E $\frac{1}{4}$ cor. sec. 34, accessible from State Highway 1 and the Old Coast Road; Point Sur 15-minute quadrangle. Ownership: Not determined (1957).

Table 17. Chemical analyses of carbonate rock samples from Pico Blanco deposit (see figure 6 for locations).

Sample	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	P ₂ O ₅
PB-1.....	2.56%	0.08%	0.44%	53.66%	0.46%	0.04%
PB-2.....	0.69	0.04	0.17	54.92	0.48	0.02
PB-3.....	3.90	0.12	0.92	52.56	0.48	0.03
PB-4.....	0.17	0.02	0.04	55.52	0.26	0.04
PB-5.....	6.12	0.10	1.27	51.43	0.19	0.05
PB-6.....	0.55	0.13	0.14	54.54	0.83	0.01
PB-7.....	0.27	0.02	0.08	55.70	0.07	0.02
PB-8.....	0.13	0.04	0.04	55.69	0.14	0.01
PB-9.....	0.50	0.07	0.12	55.30	0.24	0.04
PB-10.....	0.47	0.16	0.10	56.88	15.89	0.02
PB-11.....	0.31	0.08	0.08	55.56	0.14	0.03
PB-12.....	0.81	0.05	0.22	54.87	0.42	0.01
PB-13.....	0.66	0.05	0.21	54.78	0.52	0.03
PB-14.....	0.20	0.06	0.08	55.58	0.18	0.02
PB-15.....	0.18	0.05	0.06	55.08	0.59	0.03
PB-16.....	2.78	0.03	0.88	53.29	0.42	0.01
PB-17.....	0.70	0.05	0.20	54.82	0.48	0.02
PB-18.....	0.84	0.06	0.24	54.89	0.36	0.02
PB-19.....	0.69	0.05	0.18	55.12	0.23	0.03
PB-20*	0.84	0.13	0.21	42.40	10.96	0.03
PB-21.....	0.67	0.06	0.16	50.35	4.33	0.02
PB-22.....	1.01	0.04	0.23	54.59	0.49	0.02
PB-23.....	0.22	0.02	0.07	55.35	0.39	0.03
PB-25.....	0.62	0.02	0.13	55.00	0.37	0.05
SPB-1.....	0.94	0.47	0.20	53.47	1.30	0.11
SPB-2.....	0.76	0.08	0.13	51.14	3.66	0.05
SPB-3.....	0.32	0.06	0.07	52.36	2.80	0.05
SPB-4.....	0.21	0.05	0.05	55.21	0.49	0.05
PBy-1A.....	0.70	0.08	0.14	55.04	0.33	0.20
PBy-1B.....	0.52	0.05	0.06	55.09	0.43	0.07
PBy-1C.....	0.66	0.06	0.14	52.13	2.77	0.21
PBy-1D.....	0.58	0.05	0.10	53.81	1.43	0.20
PBy-2*	23.40	0.14	0.38	42.28	0.17	0.05
PBy-3.....	0.72	0.07	0.15	53.96	1.19	0.21
PBy-4.....	3.10	0.08	0.16	53.32	0.57	0.14
PBy-5.....	0.88	0.04	0.08	55.09	0.24	0.04
PBy-6.....	1.18	0.02	0.06	54.65	0.49	0.04
PBy-7.....	1.92	0.03	0.10	54.56	0.41	0.05
PBy-8.....	1.48	0.05	0.18	54.25	0.59	0.19
PBy-9.....	0.72	0.10	0.20	55.17	0.18	0.20
PBy-10.....	2.16	0.16	0.32	54.01	0.38	0.20
PBy-11.....	7.32	0.19	0.36	50.47	0.71	0.26
PBy-12A.....	3.92	0.11	0.23	52.83	0.53	0.21
PBy-12B*	1.12	0.06	0.12	55.30	16.95	0.01
PBy-13*	17.94	0.19	0.22	44.83	0.58	0.04
PBy-14.....	0.70	0.08	0.16	54.71	0.64	0.20
PBy-15.....	0.44	0.03	0.11	54.31	1.08	0.19
PBy-16.....	1.74	0.04	0.14	54.58	0.23	0.05

* Sample analyzed to determine range of SiO₂ or MgO or for other special purposes.

Samples PB-1 to PB-12 collected by Oliver F. Bowen and Earl W. Hart March 27, 1957, and analyzed by Abbot A. Hanks, Inc., San Francisco.

Samples PB-13 to PB-25 collected by Oliver F. Bowen June 27, 1957, and analyzed by Abbot A. Hanks, Inc.

Samples SPB-1 to SPB-4 collected by Tom Maher (previous owner) March 1958 and analyzed for Division of Mines by Abbot A. Hanks, Inc.

Samples PBy-1 to PBy-16 collected by Marshall E. Maddock October 1, 1959, (outcrops painted yellow) and analyzed by Abbot A. Hanks, Inc. (permission to publish courtesy O. P. Jenkins, owner).

Several sinuous lenses of carbonate rock as long as a mile are shown on Trask's geologic map (1926). These lenses, plus some small nearby masses, form a discontinuous belt $4\frac{1}{2}$ miles long extending from the sea coast just north of Hurricane Point southeast to the western part of Dani Ridge. The limestone is part of the Sur Series of metamorphic rocks which locally have been thrust southwestward over Cretaceous (?) sedimentary rocks along the Serra Hill fault (Trask, 1926, map and fig. 2). There has been no development or even significant testing of the limestone, and little is known about the commercial possibilities. The most northwestern lens of limestone was observed briefly where it is crossed by State Highway 1. Here it is brecciated and somewhat impure, being associated with schist and locally cut by granitic dikes. Two selected samples of limestone, collected from the highway cut at the northwest end of the deposit belt, were analyzed in 1955 and 1957 by Abbot A. Hanks, Inc.

Sample	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	P ₂ O ₅
SLS-1	0.56%	0.08%	0.30%	54.13%	1.02%	0.04%
SH-1	0.65	0.05	0.16	53.47	1.69	0.02

These samples are nearly white, fine- to coarse-crystalline material and represent the best limestone available near the highway. However, this part of the deposit probably is not of commercial value due to siliceous impurities and granitic intrusives which were not sampled. Although the southeastern limestone lenses also may be impure and less continuous than indicated by Trask, their relative accessibility warrants further examination and possible sampling (Hart 1966b, p. 66).

Tassajara deposit. Location: NE $\frac{1}{4}$ sec. 29, T. 19 S., R. 4 E., M.D., 17 miles west of Greenfield; Jamesburg 15-minute quadrangle. Ownership: Not determined.

A small deposit of white crystalline limestone was quarried many years ago as a source of lime for mortar in construction of the hotel at Tassajara Hot Springs (Fiedler, 1944, p. 203, 248, plate 9). The deposit is situated on Tassajara Road less than 3 miles north of the hot springs. Although easily accessible, the limestone is remote and impure, being cut by pegmatite dikes.

PARKFIELD-COALINGA DISTRICT (C-4)

Several deposits and prospects of carbonate rock dispersed over parts of Monterey and Fresno Counties are designated herein as the Parkfield-Coalinga district. Except for a minor amount of "brown aragonite" (Montford deposit) used to make lime in the 1880s, none of the deposits is developed.

Perhaps the most important deposits are the disconnected masses of crystalline limestone and dolomite (?) (Little Cholame and Nelson Creek deposits) which occur as fault slivers along the San Andreas fault zone. Some fault slices of fine-grained limestone similar to that of the Franciscan Formation also exist

along the San Andreas fault zone. Because of their remoteness from marketing areas, none of these deposits has been prospected to any extent. The other limestone and dolomite deposits reported appear to be too small or impure to be of more than strictly local interest.

Little Cholame (Patriquin) deposits. Location: SW $\frac{1}{4}$ sec. 31, T. 22 S., R. 14 E., and SW $\frac{1}{4}$ sec. 5 and sec. 6, T. 23 S., R. 14 E., M.D., 5 miles northwest of Parkfield and 15 miles southwest of Coalinga; San Miguel and Parkfield 15-minute quadrangles. Ownership: Not determined (1962).

An "undeveloped deposit of white marble" in sec. 6 is mentioned by Waring and Bradley (1919, p. 607). This undoubtedly is part of the sequence of three fault blocks or slivers of Sur Series limestone shown by Jennings (1958, based on unpublished mapping of N. L. Taliferro). The limestone supposedly extends $2\frac{1}{2}$ miles southeast along the San Andreas fault zone from SW $\frac{1}{4}$ sec. 31 to E $\frac{1}{4}$ cor. sec. 8. Examination of the southeast fault block in sec. 8 was made, but not a single exposure of limestone was observed. However, numerous fragments of white to gray, crystalline limestone were noted in the ravines and in the late Cenozoic gravel deposits exposed on the hills. To the northwest in SE $\frac{1}{4}$ sec. 5, limited exposures of limestone could be seen but were not visited. The deposit indicated in secs. 5, 6, and 31 to the northwest is likely to consist of small fault blocks and slivers of crushed and sheared limestone interspersed with other rock types, as is the case to the northwest along the San Andreas fault zone (see Nelson Creek deposit). However, this inference cannot be substantiated without additional field work.

Other references: Logan, 1947, p. 260; Hart, 1966b, p. 67, 69.

Montford deposit. Location: Sec. 24, T. 21 S., R. 14 E., M.D., 4 to 5 miles southwest of Coalinga; Coalinga 15-minute quadrangle. Ownership: Not determined.

Brown aragonite was reported in 40 acres of land owned by Dr. G. T. Montford (Laizure, 1929, p. 317). Logan (1947, p. 234) refers to this property as Montford marl—"a 'vein' of limestone" from which lime was made in the 1880s. The limestone is reportedly bituminous.

Nelson Creek deposits. Location: Mainly sec. 22, SW $\frac{1}{4}$ sec. 23, and N $\frac{1}{2}$ sec. 26, T. 22 S., R. 13 E., M.D., 17 miles northeast of Bradley and 15 miles southwest of Coalinga. Ownership: Possibly Hope Bagby, Hidden Valley Ranch, San Miguel (1960).

Blocks and slivers of crystalline limestone and dolomite (?) intermixed with Sur Series schist, granitic rocks, Franciscan rocks, serpentine, and various younger sedimentary rocks are found along the San Andreas fault zone on the northeast side of Nelson Creek. The carbonate rocks reportedly are exposed over a distance of more than $2\frac{1}{2}$ miles from NW cor.

sec. 22 southeast to W $\frac{1}{4}$ cor. sec. 25 (N. L. Taliaferro *in* Jennings, 1958, and *in* Jennings and Strand, 1958). Where examined in SE $\frac{1}{4}$ sec. 22 and SW $\frac{1}{4}$ sec. 23, the only carbonate rock exposed is limestone in small blocks and slivers not more than 30 to 40 feet wide and interspersed with other rock types. The limestone is principally blue gray, medium to coarse crystalline, sheared, and brecciated. Samples of typical rock were analyzed by Lydia Lofgren of the Division of Mines and Geology on February 15, 1963, as follows:

Sample	CaO	MgO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	P ₂ O ₅	Ign. loss
1	49.70%	3.08%	4.44%	0.10%	0.20%	0.04%	42.39%
2	54.50	0.17	1.03	0.11	0.23	0.04	43.27

In addition to the above type of limestone, off-white to gray crystalline limestone and dolomite are found as float in Nelson Creek and its tributaries. Presumably, this float was derived from small broken masses (to the southeast, in sec. 26 $\frac{1}{2}$) similar to those faulted masses examined in secs. 22 and 23. Although total limestone reserves may be large in the Nelson Creek area, the deposits appear to be too intermixed with other rocks and too remotely situated to be of economic interest. The deposits are about a mile from the Nelson Creek road which is about 24 miles (by road) from San Miguel.

Other references: Crawford, 1894, p. 392; Crawford, 1896, p. 629; Logan, 1947, p. 259; Hart, 1966b, p. 67, 69.

Stone Corral deposits. Location: Secs. 25 and 36 (proj.), T. 24 S., R. 15 E., and sec. 31, T. 24 S., R. 16 E., M.D., 9 to 11 miles southeast of Parkfield; Parkfield 15-minute quadrangle. Ownership: Probably Cholame Ranch (1966).

Several masses of limestone are shown northeast of Cholame Valley by W. R. Dickinson (1966, plate 2). These are portrayed as lens- and wedge-shaped fault slices that are distributed along a fault zone for 2 miles northwest of Stone Corral Canyon. The largest limestone mass has maximum dimensions of 4,500 feet by 1,200 feet. The limestone is gray green and reddish gray, fine grained, and commonly sheared. It contains dark gray chert bands and nodules and resembles limestone of the Franciscan Formation (Dickinson, 1966, p. 718).

The above deposits have not been examined by this writer.

Webb and Mingus calcite deposit. Location: Sec. 12, T. 20 S., R. 13 E., M.D., 10 miles northwest of Coalinga; Priest Valley 15-minute quadrangle. Ownership: Not determined.

A calcite deposit is reported on "Sherman Peak" (Laizure, 1929, p. 317; Logan, 1947, p. 235). Recent maps show Sherman Peak to be in sec. 10 to the west. There is no known development of the deposit. Sec. 12 is underlain by sedimentary rocks of Late Cretaceous age.

Webb and Mingus dolomite deposit. Location: Sec. 28(?) , T. 24 S., R. 16 E., M.D., 12 miles southeast of Parkfield. Ownership: Not determined.

Laizure (1925, p. 36) mentions an undeveloped deposit of dolomite in sec. 28 on the 160-acre property of E. A. Webb and S. M. Mingus in southeast Monterey County. Sec. 28 is shown to be underlain by complexly faulted and folded clastic sedimentary rocks (Upper Cretaceous and Tertiary) and by brecciated serpentine by Dickinson (1966, plate 2), who makes no mention of dolomite in his description of these rock units. However, Dickinson does show several masses of limestone 1 $\frac{1}{2}$ to 2 miles to the west (see Stone Corral deposits).

SOUTHERN SANTA LUCIA RANGE DISTRICT (C-5)

The southern Santa Lucia Range district includes the southeast half of the Santa Lucia Range, La Panza Range, and uppermost Salinas River in San Luis Obispo County (plate 1C). Although not quite as rugged as the northern Santa Lucia Range, the southern Santa Lucia and La Panza Ranges are nonetheless mountainous—rising to maximum elevations of 3,594 feet and 4,054 feet, respectively. Most of the district is fairly accessible by roads and the Southern Pacific Railroad traverses the region from north to south, connecting all major communities. Limited port facilities (oil, fishing) exist at San Luis Obispo and Estero Bays. The district is about half way between the major marketing centers at Los Angeles and San Francisco, the two cities being 400 miles apart.

Limestone and dolomite of the southern Santa Lucia Range district occur primarily as pre-Cretaceous metamorphic rocks and Miocene sedimentary rocks. The metamorphic rocks are similar to the crystalline carbonate rocks of the Sur Series farther north. In this district, crystalline limestone is found at the Navajo deposit (see below) and also is reported in SW $\frac{1}{4}$ sec. 24, T. 30 S., R. 17 E., both localities being in the La Panza Range. Localized in the northwest part of the district is bioclastic limestone of the Vaqueros Formation (lower Miocene). The two main occurrences are the Lime Mountain and Dubost deposits. Other Miocene shell deposits are reported near the Oceanic and Buena Vista mercury mines, 4 to 5 miles inland on San Simeon Creek and at various places in the Huasna and Salinas Valleys (Ireland, 1888, p. 532; Fairbanks, 1904, p. 4; Logan, 1947, p. 303, 306). These shell beds belong to the Vaqueros and Santa Margarita formations of early and late Miocene ages, respectively. Some of the shell beds, or reefs, are composed almost totally of shells and shell debris, one reportedly being 30 feet thick or more (Fairbanks, 1904, p. 4). Although some shell beds have been used locally as sources of lime, few if any are large enough or pure enough to be of economic interest.

In addition, impure carbonate rock constitutes the bulk of a thick sequence in the lower part of the Mon-

terey Formation and its lower to middle Miocene equivalents. The carbonate sequence is well developed in the southern part of the district, one sequence being 300 feet thick in Lopez Canyon. However, the carbonate beds are impure, consisting of siliceous, limy dolomite and dolomitic limestone interbedded with calcareous (foraminiferal) and dolomitic shale (see Lopez Canyon deposits). Impure calcareous and dolomitic beds in thick lower to middle Miocene sequences also have been mapped to the southeast in the Nipomo 15-minute quadrangle (Hall and Corbato, 1967) and to the northwest in the San Luis Obispo 15-minute quadrangle by this writer (unpublished). Except for the hard, often blocky dolomite, which is of value mainly for crushed rock purposes, these impure deposits probably offer little economic potential.

Younger deposits of marl and impure limestone apparently have been used locally as sources of lime but are no longer of commercial consideration. The widespread Jurassic and Cretaceous formations are not known to contain important amounts of limestone in this part of the Coast Ranges, although veins of coarse crystalline limestone cut these formations (Tassajara deposit).

At least eight deposits have been productive, but only the Lime Mountain deposit has been worked in the last 30 years or more. Prior to that, beginning in the 1880s, six of the deposits were worked locally as sources of lime rock and one (Kessler) provided onyx marble for ornamental use. The Lime Mountain deposit is still active and has yielded the only substantial production of limestone in the district. Most of the limestone produced there has been used for beet-sugar refining. No other important source of high-grade limestone is known in the district. However, moderately large reserves of cement-grade limestone are available at the Navajo, Lime Mountain, and Dubost deposits. Although none of these alone may be large enough to support a cement plant, it may be possible to utilize the adjacent Lime Mountain and Dubost deposits cooperatively. Considering the great distance from large marketing centers, however, none of the deposits of the southern Santa Lucia Range district is likely to be developed for regional use in the near future.

The limestone deposits of the district are described alphabetically below.

Almaden deposit. Location: SW $\frac{1}{4}$ sec. 34, T. 26 S., R. 10 E., M.D., 11 miles west of Paso Robles; Adelaida 15-minute quadrangle. Ownership: Not determined.

Fossiliferous limestone at an elevation of 1,500 feet is reported by Logan (1947, p. 306). Eckel *et al.* (1941, p. 557) report limestone to the east of the Mahoney (Buena Vista) mercury mine in the same vicinity. There is no known development of the Almaden deposit.

Aumaier and Rodriguez deposit. Location: Probably sec. 30 or 31, T. 30 S., R. 13 E., M.D., 7 miles

east-northeast of San Luis Obispo; San Luis Obispo 15-minute quadrangle. Ownership: Not determined; probably U.S. Forest Service (1965).

S. Aumaier and Peter Rodriguez located a claim of dolomite prior to 1925, reportedly in "sec. 13, T. 30 S., R. 13 E., at the upper end of Little Falls Canyon" (Laizure, 1925, p. 513). An analysis of the dolomite, made by Smith, Emery and Co., showed 20.44% MgO, 31.70% CaO, 0.40% SiO₂, 0.19% Al₂O₃, 0.05% Fe₂O₃, and 47.36% ignition loss. It should be noted that "Little Falls Canyon" is now known as Big Falls Canyon, the head of which lies in secs. 30 and 31, T. 30 S., R. 14 E., and does not extend as far northwest as sec. 13. The section location given by Laizure probably is inaccurate. The dolomite deposit in question may be the same as the "vein of white crystalline dolomite" described in "Little Falls Canyon" by Fairbanks (1904, p. 14).

Other references: Aubury (?), 1906, p. 80; Franke, 1935, p. 420.

Dubost deposit. Location: NW $\frac{1}{4}$ sec. 30, T. 26 S., R. 10 E., and NE $\frac{1}{4}$ sec. 25, T. 26 S., R. 9 E., M.D., 14 miles west of Paso Robles, which is reached over 20 miles of good roads; Adelaida 15-minute quadrangle. Ownership: Marion F. Davis, Adelaida Route, Paso Robles (1962).

Limestone from the Dubost deposit was burned for lime many years ago by A. Gould (Aubury, 1906, p. 79). According to W. L. Stanton, Jr. (1931, California Institute of Technology unpublished thesis), two kilns were built here; one in 1890 near the "Dubost home" (Camp Natoma) and the other in 1894 "over the hill and down the creek" (Franklin Creek?). Stanton states that the kilns were last operated in 1912. Although records are lacking, production is believed to have been small, as no extensive quarry site is known. Frank and Mary Dubost owned the deposit for many years prior to 1955, when it was acquired by the present owner.

The Dubost deposit consists of a sequence of massive limestone and minor sandstone beds that are part of or correlative with the Vaqueros Formation of early Miocene age (Loel and Corey, 1932, p. 102-104, 136-137). The limestone unit rests on sandstone of probable Late Cretaceous age and is overlain by soft shale of the Monterey(?) Formation. These sedimentary rocks have been broken into three or more fault blocks, which are successively downdropped to the northeast. Older Franciscan rocks have been brought up along Las Tablas fault, thus truncating the deposit on the south. The deposit consists of a main body of limestone and two smaller (thinner) sequences of beds to the northeast (figure 7). Obscure bedding features suggest a general south or southwest dip for the bodies, but local variations exist.

Most of the limestone is a pale buff, dense material composed almost entirely of sand-sized shell fragments cemented with calcite. Quartz, feldspar, and other impurities constitute a small percentage of the

typical limestone. Subordinate interbeds of gray to buff, pebbly coquina, calcareous sandstone, and similar rock types constitute the less pure portions of the deposit. A representative sample (Dubost #1) of typical limestone from the main body was analyzed by Lydia Lofgren of the Division of Mines and Geology in 1962 and showed 51.4% CaO, nil MgO, 5.01% SiO₂, 0.5% Al₂O₃, 0.25% Fe₂O₃, 0.05% P₂O₅, and 41.34% ignition loss.

The largest body of limestone underlies "hill 1905" west of Camp Natoma (figure 7). The limestone, which is almost continuously exposed over the crest

and south side of the hill, extends over an elliptical area half a mile long by a maximum of 900 feet wide. Most of the limestone appears to be relatively uniform, although two or three impure sandy and pebbly beds were observed. The thickness of the body is not known but probably is a minimum of 100 to 200 feet to cover the hill so thoroughly. Limestone reserves are estimated to be on the order of 120,000 tons per foot of depth and may total 20,000,000 tons or more. Additional limestone, extending half a mile west of "hill 1905" to Franklin Creek, is reported by W. L. Stanton, Jr. (1931, California Institute of Technology unpub-

Figure 7. Geologic map of Dubost limestone deposit, San Luis Obispo County.

lished thesis), who considers the exposures to be possibly "continuous or nearly so" with the main body. The exposures were not examined by this writer.

Two thin, subparallel bodies of limestone, probably separated by a fault, lie northeast of the main body. Bedding attitudes could not be measured, but overall distribution of limestone suggests the bodies are thin and dip moderately to gently toward the southwest. Reserves are difficult to estimate without drill data but probably are relatively small.

Development of the Dubost deposit has been limited to minor production of limestone (for lime), although there were two episodes of exploratory drilling. In 1946, H. W. Gould and Company held a lease on the property and did extensive core drilling, part of which was conducted north of the main deposit on the lower of two terraces (Logan, 1947, p. 303). Fourteen holes totaling 1,742 feet were drilled and an average analysis of 91.32% CaO and 5.17% SiO₂ was computed for the samples obtained. The few samples analyzed for magnesia contained less than 0.25% MgO. The company estimated (preliminary) limestone reserves at more than 50 million tons although only 1 to 2 million tons were proved by drilling (Logan, 1947, p. 304). From 1955 to late 1962, Collier Carbon and Chemical Corporation leased the deposit and did additional diamond drilling, including both vertical and diagonal holes in the main body. Results of that program are not available.

Future potential of the Dubost deposit is somewhat uncertain because of the size, location, and quality of the limestone. Based on quality alone, the limestone undoubtedly would be satisfactory for cement and certain other purposes but not for lime, chemical, and other uses where high chemical quality is important. Reserves of this deposit may be insufficient to establish a cement plant.

Huasna area. Location: NW¼ T. 32 S., R. 16 E. and E½ T. 32 S., R. 15 E., M.D., 13 to 18 miles east of Arroyo Grande; Nipomo 15-minute quadrangle. Ownership: Not determined.

According to Aubury (1906, p. 80), "an extensive deposit of buff colored limestone" is situated on the properties of Dawson, Lowe, and Mrs. R. Porter, as well as on U.S. Forest Service land. The area referred to is underlain extensively by the Monterey Formation, which commonly contains calcareous (foraminiferal) mudstone and siltstone beds, as well as impure dolomite. However, there are no deposits of limestone known to be of economic interest in the Huasna area. A description and geologic map of the rock units of this area are given by Hall and Corbató (1967).

Kessler (Kessler) deposit. Location: Secs. 9 and 16, T. 31 S., R. 15 E., M.D., 14 miles northeast of Arroyo Grande; Nipomo 15-minute quadrangle. Ownership: Not determined.

Irregular masses of onyx marble and related carbonate material are exposed intermittently over a length of half a mile in the vicinity of Salt Creek. The masses are found in sandstone and shale, apparently as fracture fillings related to the East Huasna fault. The following description of the deposit is based largely on reports by Angel (1890, p. 584-585) and Aubury (1906, p. 111-112). At the main quarry to the east (south?), the onyx occurs as steeply dipping layers 1 to 10 inches thick and varies from white to yellow, green, and red. Half a mile to the west (north?), the stone is white, faintly banded, and occurs in two layers 1 to 6 inches thick. Other small masses of carbonate rock are found on the hill between the above exposures. A chemical analysis of the onyx shows 93.86% CaCO₃, 1.43% MgCO₃, and 3.93% FeCO₃ (Waring, 1915, p. 165). Several saline springs and seeps are active in the vicinity and probably are related to the formation of the onyx.

The Kessler deposit was worked from about 1890 to 1900 through two quarries half a mile apart. The main (east) quarry was developed over a length of 50 feet and a height of 20 feet, exposing onyx marble 15 feet thick. Because the marble took a good polish and could be obtained in large slabs, it was shipped widely for ornamental uses. Total production is reported to have been more than 1,000 tons prior to 1900. Later attempts to develop the deposit were unsuccessful. However, the deposit has been utilized informally as a mineral collecting site, and much onyx marble has been taken for lapidary purposes in recent years.

Other references: Laizure, 1925, p. 527; Franke, 1935, p. 432.

Lime Mountain deposit. Location: Secs. 15 and 16, T. 26 S., R. 9 E., 18 miles west of Paso Robles; Adelaida and San Simeon 15-minute quadrangles. Ownership: Eaton and Smith, 1215 Michigan Street, San Francisco (1963).

The Lime Mountain limestone deposit has been under development since 1932, and production has been substantial. According to Logan (1947, p. 304-305) and unpublished data, commercial production was intermittent between 1933 and 1943 by Charles Taylor and in 1945 by San Miguel Lime and Development Co. Based on the sizes of the quarries reported by Logan, total amount of limestone quarried prior to 1946 probably was about 200,000 tons, well over half of which must have been sold. Records indicate that subsequent production in 1947 and in 1949 was by Essential Industries, Inc., and between 1952 and 1953 by Henry C. Dalessi, the latter operating the property for the Central Bank of Oakland. The present owner acquired the deposit in late 1953 and has operated it on a seasonal basis ever since. Total limestone produced (sold) through 1963 is estimated to be more than a million tons. All of the limestone quarried was obtained from the summit area of the main limestone body in NW¼ sec. 15 and virtually all of the production was for use in beet-sugar refining.

This deposit consists of a main body of limestone and several smaller masses lying nearby to the east and to the south (figure 8). The main body is exposed at the summit and south face of Lime Mountain through a relief of 1,000 feet. It is about a mile long in a N 65° W direction, extending from a point just west of the center sec. 15 into the NW¼ sec. 16, and is 1,000 to 2,400 feet wide. On the south flank of the mountain in SE¼ sec. 16 and the adjacent part of sec. 15 is a smaller northwest-trending limestone body roughly 2,000 feet long by a maximum of 900 feet wide. Additional limestone outcrops flank the main body to the east and northeast and probably represent two or three separate small bodies, one being about 50 feet thick near the paved road. The boundaries of the several limestone masses are partly obscured by soil and dense vegetation on the north slope of Lime Mountain and by waste dumps at the east end of the main body. According to Taliaferro (1944, figure 9), the limestone is part of the Vaqueros Formation (lower Miocene), which rests unconformably on Upper Cretaceous sedimentary rocks. The finer grained limestone is virtually identical to the Vaqueros lime-

stone exposed in the Dubost deposit 3 miles to the southeast.

Because bedding features are seldom well defined, the thickness and gross structure of the deposit are difficult to ascertain. The main limestone exposures on the south slope of the mountain appear to be essentially a dip slope, although local variations in bedding attitudes, as well as brecciation features, suggest that the deposit is disrupted by faulting. As a result, the thickness of the limestone sequence is not known. An estimated minimum thickness of 100 to 200 feet is indicated by the large outcrop area and is partly verified by quarrying which, since 1932, has descended more than 100 feet below the 1947 summit elevation of 2,230 feet. Additionally, drill holes have penetrated as much as 60 feet of limestone below the present lowest quarry level, showing an original total of more than 160 feet of limestone at the summit (W. J. Smith, 1962, personal communication).

Several grades and types of limestone are found in the deposit, but the ratios and stratigraphic relationships of the various types are not known. The predominant limestone in the quarry area is light-

Photo 15. Looking west at main quarry of Lime Mountain limestone deposit, August 1968. Quarry, situated at summit of Lime Mountain, is principal source of lime-grade limestone in Coast Ranges and is used for beet-sugar manufacture. Photo courtesy of W. J. Smith of Eaton and Smith.

buff, hard, compact, high-calcium coquina. This is composed almost entirely of shell fragments and calcium carbonate cement with minor amounts of quartz and rock grains. Small amounts of dove-gray, bituminous coquina also are present in the southwest part of the quarry. The limestone is commonly brecciated and fractured, the fissures being partly filled with dripstone or aragonite crystals. The coarse-grained limestone crops out as eraggy, soil-free exposures that weather gray. To the east of the quarry, much of the limestone is pale-buff, moderately hard, fine- to medium-grained material composed of sand-sized grains of shell debris cemented with calcite. Quartz grains and other impurities commonly constitute several percent of the finer-grained limestone, which weathers to more subdued exposures than the purer limestone. Other rocks that are occasionally interbedded with the limestone include pebbly, fossiliferous sandstone and gray shale. Between the main deposit and satellite outcrops to the south and east, siltstone and other non-carbonate rocks are sporadically exposed. Chemical analyses of the more common types of limestone are given in table 18.

Table 18. Chemical analyses of limestone from the Lime Mountain deposit, Son Luis Obispo County.

Sample	CaO	MgO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	P ₂ O ₅	Ign loss
Lime Mtn 1	46.80%	0.63%	12.66%	1.18%	0.60%	0.03%	37.67%
Lime Mtn 2 . . .	53.36	0.34	2.62	0.37	0.25	0.05	42.15
Lime Mtn 3 . . .	54.50	0.0	0.97	0.17	0.1	0.02	43.60
Lime Mtn 4 . . .	54.70	0.0	0.76	0.12	0.09	0.02	43.73
Lime Mtn. 5 . . .	54.50	0.0	1.03	0.18	0.09	0.05	43.56

Samples collected November 1962 by Earl W. Hart. No. 1 is common sandy limestone west of main quarry; no. 2 is dove-gray, bituminous coquina from southwest part of main quarry; nos. 3 and 4 are typical high-grade coquina from sugar-rock stockpile; no. 5 is composite from sugar-rock stockpile. Analyzed by Lydia Lofgren, February 6, 1963.

Development by the present owner has been conducted in the main quarry and in a surrounding stripped area and traces of all previous quarries, as well as the original summit topography, have been obliterated. The stripping program—initiated in 1958 to remove relatively low-grade (minus 95% CaCO₃) limestone, soil, and a 2-foot gray shale bed—was nearly complete in late November 1962. The stripped area is roughly circular, measures about 1,000 feet in diameter, and surrounds most of the main quarry. The owner said that as much as 60 to 70 feet of overburden had been removed in places. The main quarry is somewhat irregular in shape but is judged to be about 800 feet long by a maximum of 400 to 500 feet wide, with the long axis trending west. The north and south faces are estimated to be 60 to 70 feet high and 50 feet high, respectively, and are developed by 20- to 25-foot benches. It is planned that the main quarry, now worked from the east, will be developed from a quarry being opened on the south flank of the mountain.

Beneches are currently blasted in air-drilled holes set on 8- to 10-foot centers. Approximately half a pound

of ammonium nitrate is used per cubic yard of rock and 3,000 to 10,000 cubic yards of rock is dislodged per blast. Some secondary blasting also is necessary. The rock is loaded by two power shovels (2½- and 1¼-yard capacities) into end-dump trucks, hauled a short distance to the southeast side of the quarry, and dumped into a hopper for processing. Some selective quarrying is necessary to maintain a high-grade product.

Another quarry, called the Sycamore Springs pit, was opened recently and was yielding lime-quality rock averaging nearly 98% CaCO₃ (W. J. Smith, 1969, personal communication). This quarry is believed to be located in the satellite deposit just north of SW corner sec. 15.

Eaton and Smith's processing plant is located just southeast of the main quarry. Here, raw rock dumped in the hopper is fed over a vibrating grizzly with 8-inch openings, and the oversize is crushed in a 30-inch-by-42-inch jaw crusher. The crushed material joins the minus 8-inch rock from the grizzly and all goes to a double-deck vibrating screen with 3-inch and 8-inch openings. Oversize and undersize fractions are conveyed to separate "waste" piles for possible future use. The 3-inch-by-8-inch product is stored in a 225-ton bunker and in open stockpiles for subsequent shipment by truck 27 miles to the railroad loading facility at San Miguel. The product is then shipped by rail to sugar refineries at Spreckels and Tracy. The sugar rock produced averages close to 97% CaCO₃, fluctuating from 96 to 98.8%.

In 1962, the owner was experimenting with an agricultural limestone product which is obtained at the fines "waste" pile. Here, minus ¾-inch material is screened and processed to obtain a minus 14-mesh product. The product is trucked to the San Joaquin Valley where it is sold as "Lime Mountain Brand Agricultural Limestone." A minimum of 80% CaCO₃ is guaranteed, but the company reports that the product generally contains 90% or more CaCO₃. The present operator also occasionally sells minor amounts of ornamental stone, riprap, crushed rock, and rubble to local buyers.

Recent production (sales) of limestone has averaged about 100,000 tons per year, virtually all of which was sugar rock. The company reports that this amounts to about 65% of the material currently processed, the remainder being largely unsalable (W. J. Smith, 1962, oral communication). The operator employs 14 men at the quarry and plant and 18 to 20 truck drivers and mechanics during much of the year. In the winter, only a skeleton crew is retained to repair and maintain roads and equipment and to strip overburden and low-grade rock.

Total limestone reserves at Lime Mountain are not known, although Logan (1947, p. 304) states that "drilling and examinations are reported to indicate 75,000,000 tons or more . . .". Based on the areal exposures shown in figure 8, estimated reserves of limestone (exclusive of quality) are about 550,000 tons

per foot of depth for the main body and 100,000 tons per foot of depth for the small southern mass. Until average thicknesses are determined for each body, however, total reserves cannot be accurately estimated. Even so, total reserves at the main body are certainly large and may well be 50 million tons or more. The smaller body to the south, if structurally uncomplicated, would have an average thickness of about 50 feet and total reserves of 5 million tons. It is thought that the limestone from the entire deposit might average 90% or more CaCO_3 and thus may be a future source of cement raw material. Specific reserves of sugar rock are much smaller than total limestone reserves but cannot be determined without careful drilling and sampling. In 1962, the owner reported having a 7- to 10-year supply of limestone blocked out as a result of shallow drilling in the quarry area.

Other reference: Franke, 1935, p. 425.

Lopez Canyon deposits. SE corner sec. 36, T. 30 S., R. 13 E., M. D., and vicinity, 8 miles east of San Luis Obispo; San Luis Obispo 15-minute quadrangle. Ownership: Not determined; probably U.S. Forest Service land (1965).

Limestone and dolomite have been mentioned by several investigators to occur along the course of Lopez Canyon on both the southwest and northeast walls. These carbonate rocks occur as beds, lenses, and concretions commonly associated with siliceous and clay shales of the Monterey Formation of Miocene age. The beds are confined to the lower part of that formation and apparently comprise a stratigraphic interval having a maximum thickness of 300 feet (Fairbanks, 1904, p. 4). According to Laizure (1925, p. 523), the main limestone sequence, which is about 100 feet thick and dips 45° SW into the ridge, is prominently exposed in Fern Canyon where it joins Lopez Canyon. Here, the strata consist of dolomitic limestone and limy dolomite which are thinly interbedded with calcareous, dolomitic, and siliceous shales (Oliver E. Bowen, 1962, oral communication). The carbonate rocks generally are brown to dark gray, bituminous, fine grained, dense, hard, laminated, siliceous, and argillaceous. Weathered surfaces bleach to a light yellowish tan or gray. Four samples of typical carbonate rock were collected from the Fern Canyon section (SE cor. sec. 36) by Oliver E. Bowen and analyzed by Pittsburgh Testing Laboratories in 1959. The analyses, given below in percent by weight, show the material to be impure dolomite of variable composition.

Sample	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	P_2O_5
Lopez 1..	34.25%	1.67%	3.35%	18.40%	11.46%	0.35%
Lopez 2..	33.67	0.96	3.48	22.90	8.42	0.43
Lopez 3..	11.82	0.83	9.33	25.40	15.98	0.13
Lopez 4..	5.15	0.67	8.54	29.80	12.00	0.29

Limestone from Lopez Canyon reportedly was used as a source of lime in the 1880s (Irclan, 1888, p. 532),

but there is no record of production. In 1924, Peter Rodriguez and S. J. Rhyne located three claims near the mouth of Fern Canyon and erected a small kiln, but only a small amount of lime was burned (Laizure, 1925, p. 522). Because the carbonate deposits of Lopez Canyon are impure and of variable chemistry, they do not appear to be of future interest.

Other references: Aubury, 1906, p. 80; Franke, 1935, p. 425; Lagon, 1947, p. 305.

Morgan deposit. Location: Sec. 36 T. 32 S., R. 14 E., M.D., 5 miles northeast of Nipomo and 8 or 9 miles east of Arroyo Grande; Nipomo 15-minute quadrangle. Ownership: Not determined.

Dark-gray limestone is exposed in isolated patches 30 to 40 feet wide over a considerable distance along the tops of the ridges near Loma Pelona (Aubury, 1906, p. 80). The limestone probably is part of the Monterey Formation which underlies the southwest half of sec. 36. Apparently, the deposit was worked to a minor extent around 1900 as a source of lime rock. A kiln is situated in adjacent sec. 35.

Navajo deposit. $\text{S}\frac{1}{2}$ sec. 28 and $\text{N}\frac{1}{2}$ sec. 33, T. 29 S., R. 16 E., M. D., 20 miles east of Santa Margarita and 7 miles northwest of Pozo; Pozo 15-minute quadrangle. Ownership: Trinidad Mining Company (c/o Karl and Feree Pierce, Morro Bay) owns eight unpatented claims (Navajo 1 to 8) (1963).

The Navajo deposit consists of several westward trending lenses of Sur Series (?) limestone set as pendants in granitic rock. Although exploratory and assessment work has been fairly extensive, there has been no commercial production. The largest mass is half a mile long by a maximum of 600 feet wide. Its east end lies at the summit of hill 2805 near the SE cor. sec. 28. To the southwest, in $\text{N}\frac{1}{2}$ $\text{NE}\frac{1}{4}$ sec. 33, there is a smaller body about a quarter of a mile long and a maximum of 300 feet wide. A much smaller lens lies due east at the crest of hill 2707, and a few minor patches of limestone are exposed nearby to the west. Internal structures (bedding?) in the larger bodies generally strike $\text{N } 80^\circ \text{ E}$ and dip about 30° N , but there are some variations in attitude. Dikes and sills of decomposed granite pervade the limestone and may amount to 20% of the lenses.

The limestone is white to blue gray, medium to coarse crystalline, locally siliceous and sometimes blotchy or banded. Chemical analyses of 11 samples (table 19) showed an average of 51.82% CaO , 1.73% MgO , and 2.42% SiO_2 . Dolomite rock was not recognized in the field but may be present locally.

Development work, done mainly about 1959, consists of extensive cuts, a few test pits, an assessment tunnel, and some shallow stripping. Some shallow drilling is reported to have been done in the early 1960s, but there was no activity in May 1963 when the deposit was visited by this writer. Limestone reserves, excluding 20% for granitic dikes, are estimated to be 60,000 tons per foot of depth at the main mass and

18,000 tons per foot of depth at the southwest lens. Assuming the lenses persist at depth, total reserves recoverable by open pit mining may be on the order of 15 to 20 million tons.

Table 19. Chemical analyses of Navajo limestone deposit, La Panza Range, San Luis Obispo County.

Sample	CaO	MgO	Fe ₂ O ₃	Al ₂ O ₃	SiO ₂	P ₂ O ₅
Trinidad 1	53.60%	0.83%	0.011%	0.66%	1.34%	0.195%
Trinidad 2	49.70	3.16	0.029	1.81	2.88	0.067
Trinidad 3	52.00	0.83	0.014	0.98	3.25	0.345
Trinidad 4	51.60	1.62	0.120	0.64	2.55	0.042
Trinidad 5	50.70	2.17	0.037	0.89	2.65	0.089
Trinidad 6	53.80	0.71	0.027	0.44	1.45	0.088
Trinidad 7	52.20	0.69	0.063	0.65	3.80	0.056
Trinidad 8	53.80	0.54	0.180	1.07	1.44	0.057
Trinidad 9	51.00	3.60	0.030	0.74	0.66	0.138
Trinidad 10 ..	52.50	1.04	0.043	0.50	3.46	Nil
Trinidad 11 ..	49.10	3.88	0.054	0.64	4.11	0.058

Samples collected by Oliver E. Bowen, April 1959: 1-8 from main lens, 9 from southeast lens, 10-11 from southwest lens; analyzed by Pittsburgh Testing Laboratory June 11, 1959.

Based on the chemistry of the limestone, limited reserves, and distance from transportation facilities (30 miles by road to rail head at Santa Margarita), the Navajo deposit appears to be useful, principally as an emergency source of cement raw material.

Newsom deposit. See. 23 or 24, T. 32 S., R. 13 E., M.D., 2 to 3 miles east of Arroyo Grande; Arroyo Grande 15-minute quadrangle. Ownership: Not determined.

A flat-lying bed of soft, clayey limestone (marl), 5 to 6 feet thick, is reported in the canyon near Newsom Springs (Aubury, 1906, p. 80; Logan, 1947, p. 306). The material was burned for lime at a nearby kiln around 1900 or earlier. The deposit apparently is too small to be of economic interest.

Nipomo deposit. Location: Near Nipomo. Ownership: Not determined.

A large body of soft, marly limestone in the vicinity of Nipomo is mentioned by Ireland (1888, p. 532). The deposit was developed as a source of lime in the 1880s. The location and nature of this occurrence are not known.

Oak Flat deposit. Location: Not determined; reported west of Paso Robles. Ownership: Not determined (1962).

According to Angel (1890, p. 584), a bed of limestone at Oak Flat was developed extensively as a source of lime burned locally in the late 1880s. Although Oak Flat is not identified on recent maps, it is believed to refer to the low-lying granitic terrane 3 to 5 miles northwest of Paso Robles (Jennings, 1958; Durham, 1968). The exact location of the deposit is not known.

Other references: Aubury, 1906, p. 80; Logan, 1947, p. 306.

Santa Margarita deposit. Location: Possibly sec. 5, 6 or 8, T. 29 S., R. 13 E., M.D., 2 to 3 miles north of

Santa Margarita; San Luis Obispo 15-minute quadrangle. Ownership: Not determined; probably Santa Margarita Land and Cattle Company, 311 California Street, San Francisco (1966).

Brown crystalline limestone, exposed over a width of 20 feet and length of 1 mile, is reported north of Santa Margarita (Logan, 1919, p. 689). The limestone is said to trend northwest. Detailed geologic mapping by this writer in the area north of Santa Margarita failed to reveal such a limestone deposit, although beds of sandy algal limestone and fine-grained dolomite are interbedded with punky calcareous mudstone and shale of the Monterey Formation. These rocks do not appear to be of economic interest, and none have been quarried.

Other references: Loizure, 1925, p. 522; Logan, 1947, p. 306.

Santa Margarita Ranch deposit. Location: Near center sec. 28, T. 29 S., R. 13 E. (proj.), M.D., 1½ mile southeast of Santa Margarita; San Luis Obispo 15-minute quadrangle. Ownership: Santa Margarita Land and Cattle Company, 311 California Street, San Francisco (1966).

Massive beds of sandy coquina and oyster shell reefs as much as 10 or more feet thick are interbedded with friable sandstone of the Santa Margarita Formation (upper Miocene). The coquina is impure, consisting of broken shell debris mixed with quartz-feldspar sand. Entire shells of the giant oyster (*Ostrea titan*) comprise the purer but less extensive reefs. The deposit is developed by a narrow bench cut about 200 feet long with a maximum face of 12 feet, together with several smaller prospect cuts and trenches in the immediate vicinity. To the southwest and just below the main cut is a concrete foundation—possibly the foundation of a pre-existing crusher or other processing facility. There is no record of commercial production, although at least 1,000 tons of shells and sand were quarried at the main cut. The deposit apparently was prospected by Comar Shell Company (Los Angeles), whose lease on the property terminated about 1928 (1966, W. D. Reis, Santa Margarita Land and Cattle Co., oral communication).

Similar deposits of sandy coquina and oyster shell reefs occur at various horizons within the Santa Margarita Formation, elsewhere near Santa Margarita, and in other parts of the upper Salinas Valley.

Tassajara deposit. Location: Secs. 21 and 28, T. 29 S., R. 12 E., M.D., 4½ miles west of Santa Margarita; San Luis Obispo 15-minute quadrangle. Ownership: U.S. Forest Service land (1969).

S. Aumaier of San Luis Obispo located three claims on a deposit of white, coarse-crystalline calcite prior to 1925. The calcite occurs as veins, the largest being 12 to 14 feet wide, and was reported traceable over the length of two claims (Loizure, 1925, p. 522). One northwest-trending vein exposed by a small prospect pit near N¼ cor. sec. 28 is reported to be 3 to 5 feet thick and to consist of large, partly deformed crystals

of calcite as much as 4 inches long (Randy Tomer, 1969, personal communication). The veins occur in a sequence of Lower Cretaceous shale and sandstone, which is bordered to the south by serpentine. An analysis of the calcite by Smith, Emery, and Company shows 54.24% CaO, 0.42% MgO, 0.45% SiO₂, 0.19% Al₂O₃, 0.85% Fe₂O₃, 0.80% Mn₂O₄, and 43.40% ignition loss.

Other than short open cuts made prior to 1925, the deposit is undeveloped. The calcite veins are closely approached by roads up Tassajara Creek and along the crest of the Santa Lucia Range.

Other references: Franke, 1935, p. 426; Logan, 1947, p. 306.

SANTA YNEZ DISTRICT (C-6)

The Santa Ynez district (plate 1C) encompasses the limestone and dolomite deposits of southern Santa Barbara and southwestern Ventura Counties including the southeast end of the San Rafael Mountains of the Coast Ranges and the Santa Ynez Mountains of the Transverse Ranges. Although the deposits lie in two separate geomorphic provinces (Jenkins, 1938), they are geologically related and therefore are discussed together.

The deposits are situated in hilly to mountainous terrain that rises from sea level to maximum elevations of 6,828 feet in the San Rafael Mountains and 4,618 feet in the Santa Ynez Mountains. The westward-flowing Santa Ynez River divides the two ranges and provides access into much of the higher region. Major transportation and access routes include the Southern Pacific Railroad, which follows the coastline, and four state and federal highways. Ocean shipping facilities are limited. Santa Barbara and Ventura, with 1970 populations of 69,538 and 58,000, respectively, are the largest cities in the district. The nearest major marketing center is Los Angeles, 70 miles by road to the east of the nearest limestone deposit.

Virtually all of the limestone and dolomite deposits of the Santa Ynez district belong to formations of middle Eocene (Sierra Blanca Limestone) and Miocene (basal Monterey Formation, Temblor Formation?) ages. The Sierra Blanca Limestone, lying at or near the base of the Juneau Formation (or the equivalent Anita Shale), is sporadically present throughout the area. This unit is the only known source of high-quality limestone in the district, the Sierra Blanca deposit north of Santa Barbara being by far the largest. Here, the limestone is bioclastic, dense, hard, and apparently of sufficient purity and size to be used for cement, lime, and other purposes. However, its remote position in the San Rafael Wilderness Area in the rugged San Rafael Mountains has forestalled any development of the Sierra Blanca deposit. There appears to be more incentive at the present to retain the deposit as part of a wilderness area rather than develop it as a mineral resource. Other deposits of Sierra

Blanca Limestone are much smaller (thinner), less pure (sandy), and principally of local interest.

Because the Sierra Blanca Limestone has such a distinct fossil fauna, it has been studied thoroughly (Nelson, 1925, p. 352-354; Keenan, 1932; Dibblee, 1950, p. 25-26; Walker, 1950a; Page *et al.*, 1951, p. 1745-1749; Dibblee, 1966a, p. 20-21). Less is known about the other carbonate deposits of the Santa Ynez district.

All but one or two of the remaining deposits appear to belong to the basal part of the Monterey Formation (also called Monterey Shale) or equivalent middle Miocene formations. Two of the deposits indicated as limestone by others (Aubury, 1906, p. 80; Dibblee, 1950, p. 34-42, 79-81, plates 1-4) have been sampled and shown to be dolomite. It is suspected that other occurrences of Monterey "limestone" will prove to be dolomite or dolomitic limestone when tested. One possible exception is the Miguelito Canyon deposit—tentatively described as Monterey Formation—which apparently yielded limestone for sugar refining. Aside from use as a local source of crushed rock, dolomite of the Monterey Formation conceivably may be of sufficient quality in some places to be used as a refractory material. However, more exploration and testing needs to be done to evaluate the deposits, which commonly are sandy or siliceous.

At least seven deposits have been utilized as sources of lime and crushed rock in the Santa Ynez district. About 100,000 tons of limestone from the San Miguelito deposit produced for lime, and a minor amount apparently was produced at the Matilija Canyon area. Perhaps as much as 2 million tons of crushed and broken stone (including riprap, road base materials, concrete aggregates, and filter rock) were obtained from the Missile City, Bee Rock, El Jaro, Alisal, and Nojoqui Canyon deposits. Production of limestone for lime ceased many years ago, when reserves at San Miguelito were depleted. On the other hand, production of dolomite and limestone for crushed rock has occurred sporadically according to need. Deposits that may be of significant future interest, other than for crushed rock uses, include 1) the Sierra Blanca limestone deposit which has large reserves of good quality material, and 2) various deposits which contain large reserves of dolomite possibly adequate for refractory or other special purposes.

The deposits of the Santa Ynez district are described alphabetically below.

Alisal deposit. Location: Sec. 21 (proj.), T. 6 N., R. 31 W., S.B., nearly 1 mile southwest of Solvang; Los Olivos 15-minute quadrangle. Ownership: Not determined.

Basal limestone of the Monterey Formation is exposed along the south bank of the Santa Ynez River where it extends west-northwest over a strike length of 3,000 feet and dips steeply north. The deposit is about 50 feet thick and consists of hard, light-gray, algal limestone, the basal portion of which consists of

calcareous and tuffaceous, pebbly, fossiliferous sandstone (Dibblee, 1950, p. 81, plate 4).

The deposit is developed by a quarry at its east end and was worked intermittently from 1928 to 1941. The limestone was crushed to various sizes and used for road construction (surfacing?) by Santa Barbara County. No analyses are available, and the deposit may be dolomitic.

Bee Rock deposit. Location: SW¼ sec. 31, T. 6 N., R. 29 W., S.B., 7½ miles north of Naples and 18 miles northwest of Santa Barbara; San Rafael Mountain 15-minute quadrangle. Ownership: Not determined.

Dense, massive, light-gray limestone, containing several layers of chert, is exposed prominently at Bee Rock 2 miles south of Cachuma Dam. The deposit dips gently to the south and is truncated down dip by a north branch of the Santa Ynez fault. The limestone is a basal unit of the Monterey Formation (Miocene) which locally rests on Matilija Sandstone(?). A thin overburden of siliceous shale overlies the limestone in places. The maximum thickness of the limestone sequence is 200 feet (Dibblee, 1966a, p. 47, 89-90, plate 3; T.W. Dibblee, Jr., 1963, personal communication).

The deposit extends over a strike length of half a mile, a maximum width of 900 feet, and a relief of more than 500 feet. Based on topography, limestone reserves above the base (1,800 feet elevation) of the sheer cliff defining the south side of Bee Rock are estimated to be about 6 million tons. Total reserves of the deposit cannot be estimated, as the average thickness is unknown. Although reserves are relatively large, it is not known if sufficient limestone is available for cement manufacture. Further, the chemical quality of the limestone is not known and needs to be determined—particularly because carbonate rock of the Monterey Formation is generally dolomitic and siliceous.

The limestone was used in construction of the Cachuma earth and rock fill dam, completed in 1953. Apparently a large amount of limestone was used as a rock blanket or riprap. The limestone came from a quarry on the south side of Bee Rock, 2 miles south of the dam.

El Jaro deposits (including Dibblee quarry). Location: Secs. 19, 20, 28, 29, 30, and 33 (proj.), T. 6 N., R. 33 W., S.B., 6 to 8 miles southeast of Lompoc; Lompoc 15-minute quadrangle. Ownership: W. C. H. Dibblee (Rancho San Julian) (1950).

Gently folded carbonate beds at the base of the Monterey Formation are exposed extensively on both sides of El Jaro Creek, as shown by Dibblee (1950, plate 3). According to Dibblee (p. 79), the carbonate unit is a maximum of 150 feet thick and consists of 70 feet of "pure limestone" which grades downward into "calcareous tuffaceous sandstone with local occurrences of conglomerate at the base". The carbonate unit grades by interbedding into the overlying Monterey shale. Actually, the rocks exposed along State

Highway 1 are largely dolomite as shown by the analyses in table 20. Where sampled, the dolomite is generally brown to grayish brown and bituminous, weathering to a light buff color. It is also hard, dense to slightly vuggy, locally brecciated, and commonly contains concentrations of replacement chert. The beds are faintly laminated to massive, commonly being broken and contorted. The main deposits lie in S½ secs. 19, 20, and 28, and W½ sec. 29. Dolomite reserves may be large; more sampling, and perhaps drilling, needs to be done to evaluate the quality and sizes of the various deposits. It is possible that some of the dolomite, if selectively quarried, may be of value as a refractory material.

Table 20. Chemical analyses of carbonate rock (Monterey Formation) from the El Jaro deposit, Santa Barbara County.

Sample	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	P ₂ O ₅
LJ-1	6.48%	0.66%	0.83%	29.98%	17.89%	0.11%
LJ-2	6.03	0.55	0.94	28.84	19.07	0.05
LJ-3	1.86	0.62	1.71	30.02	19.88	0.14
LJ-4	1.89	0.29	0.58	30.59	20.18	0.22
LJ-5	3.53	0.62	0.51	30.49	19.46	0.12
LJ-6	3.70	0.18	1.96	29.65	19.51	0.28
LJ-7*	2.33	0.70	1.12	53.14	0.22	0.05

Samples collected by Oliver E. Bowen at intervals from south to north in road cuts east of El Jaro Creek in E½ of SE¼ sec. 19 (proj.), T. 6 N., R. 33 W. Samples LJ-1 to LJ-4 are from lower beds; LJ-5 and LJ-6 are from middle beds; and LJ-7 is from upper bed. Most samples are bituminous, and some contain small patches of chert. Sample LJ-1 is brecciated. Analyzed by Abbot A. Hanks, Inc., 1956.

* Analysis questionable, as hand specimen retained is dolomite.

One of the carbonate deposits east of El Jaro Creek was worked intermittently from 1928 to 1944 through a large quarry located in SW¼ sec. 20. According to Dibblee (1950, p. 80), "the limestone here is about 40 feet thick, grading upward into brittle cherty shales. About 15 feet of conglomerate occurs at the base of the limestone". The beds dip north into the hill. Production has been limited to crushed rock utilized for road construction (surfacing) in the Lompoc area.

La Salle-Sloan Canyon deposits. Location: Approx. secs. 11 and 12 (proj.), T. 6 N., R. 35 W., S.B., 3½ to 5 miles west-southwest of Lompoc; Point Arguello 15-minute quadrangle. Ownership: U.S. Naval Missile Facility (west half only).

Dibblee (1950, p. 79-80, plate 3) shows four elongate exposures of limestone, each half a mile long or less, that form a west-trending arcuate belt 2 miles long within the Monterey Formation. The deposits are crossed by La Salle Canyon on the west and Sloan (San Pascual?) Canyon on the east. The limestone beds have a maximum thickness of 100 feet and dip steeply north. The Tranquillon Volcanics (agglomerate) underlies the limestone unit, and shale of the Monterey Formation overlies the unit. "The limestone is similar to that of El Jaro Canyon, consisting of pure limestone grading downward into calcareous sandstone" (Dibblee, 1950, p. 80). As at the El Jaro deposits, the carbonate rock at La Salle and Sloan Can-

yons is probably dolomitic. The deposits are undeveloped. Access is via the La Salle Canyon road.

Las Positas Ranch deposit. Location: 3 miles west of Santa Barbara in "Veronica Valley". Ownership: T. W. Moore, Santa Barbara (1925).

Coarsely crystalline limestone of yellowish color is said to have been used for "cement" in construction of the Santa Barbara Mission, but tests show the material to be of no commercial value. The precise location of this deposit is unknown and it is not mentioned by Dibblee (1966a), who mapped the area in detail.

Other references: Aubury, 1906, p. 80; Huguenin, 1917, p. 739; Tucker, 1925, p. 553.

Los Prietos deposit. Location: Sec. 11 (proj.), T. 5 N., R. 27 W., S.B., 8 miles north of Santa Barbara; Gibraltar Dam 15-minute quadrangle. Ownership: Not determined.

Logan (1947, p. 310) reports a deposit of limestone south of the serpentine in which the Los Prietos mercury mines are located. This prospect is probably the same as the bed of hard, white, algal limestone that is a maximum of 10 feet thick and occurs near the top of the "Temblor" sandstone (middle Miocene). The limestone, which is exposed south and west of Gibraltar Dam, is reported to be impure (Dibblee, 1966a, p. 44). There is no known development.

Matilija Canyon deposits. Location: Secs. 22, 23, 24, and 25, T. 5 N., R. 24 W. and sec. 19, T. 5 N., R. 23 W., S.B., $5\frac{1}{2}$ to 8 miles west-northwest of Ojai; Ventura 15-minute quadrangle. Ownership: Not determined, but in Los Padres National Forest.

Several deposits of limestone have been reported from both sides of Matilija Canyon under various names (Argilla group of claims, Matilija claims, Ventura Cement Company, and Ojai Cement Company). Most, if not all, of these deposits consist of Sierra Blanca Limestone, a prominent unit that is intermittently present at or near the base of the Juncal Formation (middle Eocene). The distribution of the Sierra Blanca Limestone deposit in the Matilija Canyon area is not known in detail but is shown in a general way by Merrill (1954). He shows the limestone to occur in two places at the base of the Juncal, which rests on Cretaceous strata. The thicknesses of the limestone deposits are not known; but the largest is over a mile long, extending westward along the projected north boundary of sec. 25, T. 5 N., R. 24 W. The other deposit lies about a mile to the west in $S\frac{1}{2}$ sec. 22 and is about two-thirds of a mile long. Both deposits lie in extremely brushy, rugged terrain on the north flank of the Santa Ynez Mountains within a mile of the road up Matilija Canyon. Presumably, these are the principal deposits described in the past as potential sources of cement rock. Another limestone deposit is suggested north of Matilija Creek in sec. 19—possibly along the trend of the basal Juncal—and also may be Sierra Blanca Limestone.

Because of difficult access, it may be years before the economic potential of these deposits is known. Some data from past exploration indicate that the deposits are siliceous and of value principally for cement. However, the sizes of the deposits are unknown. The various efforts to develop the limestone deposits in Matilija Canyon are summarized below.

Argilla claims—located by E. Duryea in secs. 23 and 24. The claims cover a "massive bed of limestone on the south side of cañon, striking east and west, dipping south" (Huguenin, 1917, p. 762). It has been sampled frequently, an average reported analysis being 16.015% SiO_2 , 5.32% Al_2O_3 and Fe_2O_3 , 42.63% CaO , 1.119% MgO , and 34.19% CO_2 .

Matilija claims—2 claims in sec. 19, T. 5 N., R. 23 W. An outcrop of hard blue limestone exposed on a ridge crest north of Matilija Creek is reported to be 75 to 100 feet thick and half a mile long (Tucker and Sampson, 1932, p. 266). The deposit is undeveloped and of difficult access, being situated half a mile north of Stingley's Hot Springs (site) in Matilija Canyon.

Ventura Cement Company—owns 400 acres of land in secs. 22, 23, 26, and 27. A compact, fine-grained, gray limestone with an east strike and steep southerly dip is exposed in a main southwest tributary to Matilija Canyon. The limestone is described as being "in at least two strata, separated by 300 feet of shale. These two strata are approximately 75 and 175 feet thick, respectively" (Tucker and Sampson, 1932, p. 268). The deposit can be traced to the west about half a mile. All of the published analyses show the limestone to be somewhat impure, with silica being especially high (Huguenin, 1917, p. 762; Tucker and Sampson, 1932, p. 268). Selected samples, however, reportedly run as high as 97.86% CaCO_3 . The company explored the deposit with open cuts. Remains of an old kiln, apparently used to burn lime many years ago, are reported in the bottom of Matilija Canyon.

Ojai Cement Company—apparently investigated the Sierra Blanca Limestone deposits in Matilija Canyon about 10 to 15 years ago (Oliver E. Bowen, 1964, oral communication; based on a consulting report by Frank Wicks). The deposit investigated was reported to be a maximum of 60 feet thick. Associated calcareous shale was believed to be blendable with the limestone. Apparently there has been no development work done following this preliminary investigation.

Other references: Tucker, 1925, p. 239–240; Logan, 1947, p. 348–349.

Missile City (Lind) deposit. Location: $SE\frac{1}{4}$ sec. 19 and $SW\frac{1}{4}$ sec. 20 (proj.), T. 6 N., R. 34 W., S.B., 4 miles south-southwest of Lompoc; Lompoc 15-minute quadrangle. Ownership: Missile City Rock Corporation, 2185 Huntington Drive, San Marino (1963).

Dolomite exposed on the north flank of La Tinta Hill was first developed in the late 1950s when Missile City Rock Corporation drilled and tested the material as a source of crushed rock for concrete and base materials.

The deposit is believed to be the same as the J. C. Lind "limestone" deposit, which was sampled many years ago and found to be too high in magnesia for use in sugar refining (Huguenin, 1917, p. 739). Production of dolomite began in 1960, principally for construction uses at the nearby U. S. Air Force and missile facilities. After more than a million tons of dolomite were produced, operations reportedly ceased August 1, 1963. The quarry, referred to as the Lompoc quarry by the present operator, was operated again from 1964 through 1968 by Schmidt Construction, Inc., P.O. Box 118, Camarillo, California—mainly for the production of riprap (unpublished records).

The deposit consists of a sequence of poorly stratified dolomite that constitutes a basal member of the Monterey Formation (Miocene). The dolomite is exposed as a bold knoll (elevation 1,300 feet) on a north spur of La Tinta Hill and also makes up much of the debris in the adjacent landslides (T. W. Dibblee, Jr., 1964, oral communication; Dibblee, 1950, plate 3). Although the deposit was not visited by this writer, a composite sample (washed, crushed) from a finished-product stockpile was obtained (collected by H. B. Goldman, July 1962) for examination. The sample indicates that much of the dolomite is light buff to tan, hard, dense, and commonly composed of algal(?) debris. However, some of the dolomite is darker (gray, grayish brown), slightly vuggy, or sandy. A composite chemical analysis made by Matti Tavela and Lydia Lofgren of the Division of Mines and Geology, 1963, showed the following: 7.2% SiO₂, 0.80% Al₂O₃, 0.36% Fe₂O₃, 17.1% MgO, 30.3% CaO, 0.28% K₂O, 0.54% P₂O₅, and 42.2% ignition loss. Variations in the types of dolomite present are observable in the sample and some of the dolomite may be of sufficient quality for use as a refractory material. However, distribution and reserves of the various kinds of dolomite are unknown.

Most of the dolomite produced by Missile City Rock Corporation apparently was taken from a hillside quarry at the main exposures north of La Tinta Hill. However, in mid-1962 it was reported that the main quarry was inactive and that dolomite was being produced from outcrops to the east (H. B. Goldman, 1964, oral communication). In the early operations, each quarry blast loosened about 40,000 tons of rock, about a month's supply. According to Bergstrom (1961, p. 101–105), the loose rock was bulldozed over a cliff to the plant level, causing additional breakage. From the talus storage pile the dolomite was transferred to a grizzly and screen where minus ¾-inch rock was wasted, the oversize being crushed and sent to a large surge pile. Next, the rock was conveyed to a screening tower (250-tons-per-hour capacity) for secondary crushing and screening to six different sizes from 1½ inches to rock dust. The various size fractions were blended as necessary (including addition of river sand for concrete aggregate) to produce base materials and concrete and bituminous aggregates, most of which were

used at the Point Arguello missile facilities and Vandenberg Air Force Base. Considerable amounts of larger sized rock also were sold for riprap, slope protection, and filter rock, some being shipped as far as Los Angeles.

Other references: Aubury, 1906, p. 80; Logan, 1947, p. 309; Dibblee, 1950, plate 3.

Mono Creek-Blue Canyon deposits. Location: Mainly NW¼ and SE¼ T. 5 N., R. 26 W., S.B., 7 miles northeast of Santa Barbara; Gibraltar Dam 15-minute and Carpinteria 7½-minute quadrangles. Ownership: Not determined.

Detached masses of Sierra Blanca Limestone are exposed in two areas: 1) as an elongate belt extending for 3 miles along the north wall of Blue Canyon, and 2) to the northwest on both limbs of the Mono syncline which is traversed by Mono Creek. In both areas, the limestone unconformably overlies Espada Shale (Cretaceous) and is conformably overlain by the Juncal Formation (middle Eocene). The distribution of the limestone is shown by Walker (1950a, plate 1) and Dibblee (1966a, plate 1). The limestone is similar to that at the Sierra Blanca deposit to the north, being light gray to buff, hard, dense and massive. It consists largely of bioclastic debris (algae, corals, foraminifera) but is not as pure as the deposits to the north. Quartz sand is commonly present and chert pebbles are found at the base of the unit. At Mono Creek the limestone reportedly averages 12 feet thick, although it attains a thickness of 35 to 40 feet at the southeast end of the exposures. To the southeast, at Blue Canyon, the limestone is 10 to 50 feet thick, averaging 20 feet.

The only chemical analysis available was made from a channel sample representing 35 to 40 feet of limestone thickness at the southeast end of the Mono Creek deposits. The analysis, made by Abbot A. Hanks, Inc., shows 51.12% CaO, 1.36% MgO, 0.52% Al₂O₃, 0.45% Fe₂O₃, and 4.76% SiO₂ (Walker, 1950a, table 1).

Because the deposits have limited reserves of high quality limestone and are remotely situated with respect to markets, development is likely to be limited to local use. The limestone is accessible over dirt roads via Camuesa Canyon and Romero Saddle. There is no known development to date.

Other reference: Page *et al.*, 1951, p. 1745–1749.

Nojoqui Canyon deposit. Location: S½ sec. 25 (proj.), T. 6 N., R. 32 W., S.B., 3½ miles south of Buellton; Los Olivos 15-minute quadrangle. Ownership: Live Oak Ranch, Buellton (1959).

A prominent exposure of Sierra Blanca Limestone (middle Eocene) occurs west of Nojoqui Creek and the parallel U.S. Highway 101. The main part of the deposit occupies the nose of an eastward-plunging anticline but bifurcates, extending up both sides of the canyon to the west where it pinches out in sec. 26. Altogether, the limestone extends discontinuously(?)

for 2 miles up the south side of the canyon. According to Dibblee (1950, p. 25), "it consists of about 50 feet of gray-white, hard, sandy, algal limestone." It rests unconformably on the Jalama Formation (Cretaceous). At one time the material was quarried for road material (Dibblee, 1950, p. 25, 80, plate 4).

San Miguelito (Union Sugar) deposit. Location: Possibly S½ sec. 18 or N½ sec. 19 (proj.), T. 6 N., R. 34 W., S.B., 3½ to 4 miles southwest of Lompoc; Lompoc 15-minute quadrangle. Ownership: C. S. Larsen, Lompoc (1925).

On the north side of San Miguelito Canyon, five small limestone deposits were worked to depletion by Union Sugar Company from about 1900 to 1919. During that interval, approximately 100,000 tons of limestone were produced for use in sugar refining. The material was hand cobbled and hauled 6 miles by wagon to Lompoc. Rail shipments were made from there to Betteravia and, for a while, to Oxnard.

Broken and distorted beds of "pure white fossiliferous limestone", which graded into "siliceous limestone conglomerate", occurred as five distinct deposits over 40 acres of land (Huguenin, 1917, p. 740). The deposits apparently are depleted but may have been part of what was mapped as Quaternary landslide (Dibblee, 1950, plate 3). According to Dibblee (1964, oral communication), the landslide debris north of San Miguelito Creek is largely composed of "limestone" which is typical of the basal part of the Monterey Formation. That the landslide material was worked is indicated by the remnants of several small pits there. However, the identification of the Union Sugar deposits is tentative, as available analyses show the carbonate rock of the Monterey Formation to be generally dolomitic.

Other references: Aubury, 1906, p. 81-82; Tucker, 1925, p. 553.

Sierra Blanca deposit. Location: SE¼ T. 7 N., R. 27 W., SW¼ T. 7 N., R. 26 W., and N¼ T. 6 N., R. 26 W., S.B., 15 to 17 miles north of Santa Barbara; San Rafael Mountain and Gibraltar Dam 15-minute quadrangles. Ownership: Lies within Los Padres National Forest (San Rafael Wilderness Area).

The Sierra Blanca limestone deposit is situated a few miles south of Big Pine Mountain which, at 6,828 feet elevation, is the highest point in the San Rafael Mountains. The deposit is exposed as an elongate belt traversing elevations ranging from 3,100 to 4,900 feet. Except where its western end is crossed by Forest Service road, the limestone belt is nearly inaccessible. Because of its remote location, the deposit remains undeveloped although mapping and limited sampling indicate large reserves of good quality limestone. Around the turn of the century, the east end of the deposit was examined near the Moraga Ranch as a source of lithographic stone by the Loma Blanca Lithographic Stone Company (Aubury, 1906, p. 80). However, it was considered unsuitable for lithographic use.

The limestone deposit is exposed as a continuous belt that extends 5½ miles southeastward from the East Fork of Santa Cruz Creek (1 mile west of Big Pine Mountain Road) to a point 1 mile west of Mono Creek (see figure 9). It consists of a distinctive sequence of middle Eocene bioclastic limestone which was named the Sierra Blanca Limestone by Nelson (1925, p. 352-354). The Sierra Blanca Limestone also is exposed 1 to 2 miles to the north along the Big Pine Mountain road, but these deposits appear to be too small to be of economic value. Locally, the carbonate unit rests unconformably on Upper Cretaceous sedimentary rocks and is overlain conformably by Eocene shale and sandstone. The limestone unit dips moderately to steeply northeast, although there may be local variations due to folding and faulting.

Much of the limestone is pale buff, or, less often, grayish buff to brownish gray, and weathers to a very light gray. Typically, it is dense, hard, poorly bedded, and breaks with an uneven fracture. It is composed of fine to coarse organic debris derived from algae, Foraminifera, and various megascopic shell forms. Occasional impure, sandy horizons are reported, particularly in the upper part of the unit (Keenan, 1932, p. 65). The bulk of the unit is relatively pure, as indicated by the chemical analyses in table 21. The limestone is of adequate quality for cement manufacture and if analyses are representative, some of the limestone appears to be sufficiently pure for use in lime and chemical manufacture.

Table 21. Chemical analyses of limestone from the Sierra Blanca deposit, Santa Barbara County.

Sample	CaO	MgO	Al ₂ O ₃ + Fe ₂ O ₃	SiO ₂	P ₂ O ₅
M. F. KEENAN¹					
930 K	50.73%	3.00%	1.80%	1.60%	trace
930 P	54.32	0.71	0.94	0.96	trace
930 Q	55.33	0.32	0.56	0.24	trace
930 R	54.88	0.66	0.66	0.42	none
G. W. WALKER²					
5	53.07	1.14	0.33	2.01	ND
CALIFORNIA DIVISION OF MINES AND GEOLOGY³					
SB 1	54.31	0.58	0.48	1.04	0.06%
SB 2	54.47	0.66	0.46	0.76	0.08
SB 3	54.31	0.53	0.56	0.94	0.06
SB 4	54.60	0.62	0.52	0.48	0.05
SB 5	54.77	0.54	0.32	0.56	0.08
SB 6	54.70	0.59	0.34	0.44	0.08
SB 7	54.90	0.52	0.32	0.28	0.06
SB 8	54.70	0.46	0.44	0.62	0.05

¹ Samples collected by M. F. Keenan, September 1930, from bank of Indian Creek and represent the middle 55 feet of the stratigraphic thickness of the 225-foot-thick limestone unit. Analyzed by Leslie Larrieu, Los Angeles (Keenan, 1932, p. 70).

² Composite grab sample from Big Pine Mountain road cuts representing 70 to 80 feet of stratigraphic thickness. Analyzed by P. T. Bee, Abbot A. Hanks, Inc., San Francisco (Walker, 1950a, p. 5).

³ Grab samples collected at about 40-foot intervals from west to east along Big Pine Mountain road by Oliver E. Bowen, California Division of Mines and Geology. Analyzed by Abbot A. Hanks, Inc., San Francisco, 1953. ND = Not done.

Limestone reserves are not known, either for the total deposit or for any part of it. Total reserves obviously are large but cannot be calculated without knowledge of the average thickness of the limestone unit. The thickest part is reported to be 225 feet at Indian Creek (Keenan, 1932, p. 65). Just east of the Big Pine Mountain road, the most accessible part of the deposit, the thickness probably exceeds 70 to 80 feet (Walker, 1950a, p. 5) and reserves may be several million tons or more. Large reserves also may exist at "Sierra Blanca Mountain" where the limestone is boldly exposed. The limestone unit pinches out $1\frac{1}{2}$ miles southeast of there.

Because of transportation and access difficulties, it may be a long time before the limestone is of economic interest. At the present time, the west end of the deposit is about 35 miles by road from the nearest railhead and even farther from port facilities. The nearest paved road, at Mono Public Camp, is 18.3 miles from the limestone deposit.

Other references: Huguenin, 1917, p. 739; Nelson, 1925, p. 352-354; Logan, 1947, p. 310; Page *et al.*, 1951, p. 1745-1749; Gower *et al.*, 1966, p. A25-A26.

Figure 9. Map of Sierra Blanca Limestone, Santa Barbara County.

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Index to Deposits

All known deposits are listed alphabetically. When a deposit is known by more than one name, each additional name is also listed alphabetically and cross-referenced to the name by which the deposit is generally best known. For example, the reader looking for *Agri-cultural Lime and Compost Company* is directed to *San Francisco Bay Shell*.

Deposits described in the text can be located in the text alphabetically under the district (see Contents for district organization). The deposits shown on the index map (plate 1) may be located on the map by district and deposit numbers. The deposits are numbered from north to south within three subprovinces or regions (A, B, C).

A few deposits and prospects described in the text are not located on plate 1. These deposits are indicated by "ND" under deposit number.

Deposit	District	No.
A.S. and R.	C-1	8
Agricultural Lime and Compost Co. (see San Francisco Bay Shell)		
Alisal	C-6	6
Almaden	C-5	3
Argilla (see Matilija Canyon)		
Aumaier and Rodriguez	C-5	7
Baldy Ryan	B-4	13
Barbee Ranch	C-1	1
Bordin (see Hartnell Group)		
Bordin Ranch	C-1	11
Barnes Construction Co. (see Quail Creek)		
Bay Shell Co. (see San Francisco Bay Shell)		
Beck Dredging Co. (see Pioneer Shell Co. under San Francisco Bay Shell)		
Bee Rock	C-6	8
Bender	B-2	6
Benicia Cement Works	B-2	9
Bernal	B-4	5
Bethlehem Steel Co. (see Natividad)		
Bird Canyon Ledge	C-1	14
Bixby Creek	C-3	2
Bixby Mountain	C-3	3
Black Ranch	B-1	1
Black Mountain (see Monte Bella Ridge; Permanente)		
Bluerack Mountain	C-1	31
Bond (see Monte Bella Ridge)		
Bonnie Daan	B-5	6
Bryan and Pearce-Twahy (Ideal Cement Co.)	C-1	4
Burkhart and Teaford (see Marlite)		
Burns Valley	A-3	9
Buzzards Roost	C-1	26
Cahill Ridge	B-3	21
Calera Hill (see Rackaway)		
Calero	B-4	11
California Aggregates (Rayce)	B-3	14
California Chemical Corp. (see FMC Corp. under San Francisco Bay Shell; Westvaca)		
California Onyx Co. (see Wilbur Springs)		
California Onyx Marble (see Talenas Springs)		
Capay Valley	A-3	10
Caplatzi Quarry (see Pacific Limestone Products Co.)		
Carnegie	B-3	9
Castro Valley	B-4	15
Cement Hill	B-2	2
Chalk Mountain	A-3	4

Deposit	District	No.
Chalane Creek	C-1	ND
Clark Ranch	B-4	ND
Coast Ridge	C-3	9
Coleman Gulch (see Kahlman Gulch)		
Collins	B-3	6
Cowell (see Cowell Home Ranch; Cowell-Thompson Creek; IXL; Lime Ridge; Limekiln Creek [near Lucia])		
Cowell Home Ranch	B-5	7
Cowell-Thompson Creek	C-1	30
Crawe Ranch	C-1	ND
Daniels	A-3	2
Davis and Jordan (see Cowell Home Ranch)		
De Dera Quarry (see Pacific Limestone Products Co.)		
Deming's Point	B-2	5
Dibblee Quarry (see El Jara)		
Dicky's Quarry (see Cement Hill)		
Douglas Ranch (see Las Galas Lime Co.)		
Dubast	C-5	2
East Gabilan	C-1	13
Eaton and Smith (see Lime Mountain)		
El Jara	C-6	5
Ellis (see Las Galas Lime Co.)		
FMC Corp. (see Westvaca; San Francisco Bay Shell)		
Fashauer Ranch	A-2	4
Fisher Ranch	A-2	2
Flint-Steinbeck	C-1	5
Fremont Peak	C-1	12
Gallegas (see Mission Lime Marl)		
Gambetta (see South Bay Dredging under San Francisco Bay Shell)		
Garner-Harris	C-1	17
Guadalupe Creek	B-4	9
Guadalupe Lime Co. (see Guadalupe Creek)		
Guadalupe Portland Cement (see San Jose Cement Co.)		
Guadalupe Reservoir	B-4	10
Hackett	A-1	5
Hamilton	C-1	28
Hamilton Dolomite (see Westvaca)		
Horkinson (see Oil Canyon)		
Harlan (see Hamilton)		
Harmony Hills	C-1	6
Harris (see Garner-Harris; Palmtag-Harris)		
Hartnell Group	C-1	25
Haskins (see Westvaca)		
Healdsburg Marble Co.	B-1	3
Highway One	B-3	13
Hilltop	B-3	23
Hallister Dolomite (see Westvaca)		
Halmes	B-5	4
Happer (see Lime Ridge)		
Harse Canyon	C-3	8
Huasna Area	C-5	ND
IXL	B-5	1
Ice Cream Grade	B-5	2
Ideal Cement Co. (see San Francisco Bay Shell; Rackaway; Bryan and Pearce-Twahy; Ideal Cement Co.—San Juan Bautista Plant)		
Ideal Cement Co.—San Juan Bautista Plant	C-1	ND
Inorganic Chemicals Division, FMC Corp. (see FMC Corp. under San Francisco Bay Shell; Westvaca)		
Inverness Park	B-2	7
Jacoby Creek	A-1	1
Jamesburg (see Lambert Ranch [Jamesburg])		
Jahnstan	A-1	7

ND—Location not determined

<i>Deposit</i>	<i>District</i>	<i>No.</i>	<i>Deposit</i>	<i>District</i>	<i>No.</i>
Jolon	C-3	ND	Oil Canyon	B-3	2
Junipero Serra	C-3	10	Ojai Cement Co. (see Matilijo Canyon)		
Kaiser Aluminum and Chemical Corp. (see Notividad; Kaiser-Horris)			Old Mission Portland Cement Co. (see Ideal Cement Co.—San Juan Bautista Plant)		
Kaiser Cement and Gypsum Corp. (see Permanente)			Olema	B-2	10
Kaiser-Horris	C-1	20	Orindo	B-3	3
Kalkor (see Pacific Limestone Products Co.)			Ortley Shell Co. (see San Francisco Bay Shell)		
Kennedy Road	B-4	4	Pacific Corrojo Marble Co.	C-3	ND
Kessler (Kessler)	C-5	5	Pacific Cement and Aggregates (see Son Vicente Creek)		
Kohlman (Coleman) Gulch	B-1	6	Pacific Limestone Products Co.	B-5	10
Lo Solle-Sloan	C-6	2	Pacific Portland Cement Co. (see Cement Hill; Bryon and Pearce-Twamy; Ideal Cement Co. under San Francisco Bay Shell; Ideal Cement Co.—San Juan Bautista Plant)		
Lambert Ranch	A-3	3	Palmtoe-Horris	C-1	18
Lombert Ranch (Jomesburg)	C-3	5	Parkhurst Ridge	A-1	8
Las Positos Ranch	C-6	ND	Patriquin (see Little Cholome)		
Lime Mountain	C-5	1	Patterson Pass	B-3	7
Lime Ridge	B-3	1	Peasley Gulch	B-5	9
Limekiln Creek (near Chualar)	C-3	1	Permanente	B-4	3
Limekiln Creek (near Lucio)	C-3	11	Picordo Ranch	B-3	15
Lind (see Missile City)			Pico Blanco	C-3	6
Little Cholome	C-4	4	Pilarcitos Creek	B-3	22
Lackhort Tract (see Inverness Park)			Pioneer Shell Co. (see San Francisco Bay Shell)		
Lampac quarry (see Missile City)			Pleasanton	B-3	10
Lane Star Cement Co. (see Son Vicente Creek)			Point Reyes (see Inverness Park)		
Lopez Canyon	C-5	8	Pope Valley	B-1	5
Los Gatos Lime Co.	B-4	7	Porter	C-1	24
Los Prietos	C-6	9	Power Line	C-1	23
Los Vergeles	C-1	2	Purviance Ranch	B-1	4
Lyndon	B-4	8	Quail Creek	C-1	32
Monzanita	A-3	6	Quinn Ranch	A-2	3
Marble Peak (see Coast Ridge)			Reeves Northeast	C-1	21
Marks Materials, Inc. (see Rockaway; Skyline)			Rhodes and Jamieson (see Rackaway)		
Marlite	C-2	1	Richter (Rickter)	A-1	4
Martin Ranch	C-1	16	Rockaway	B-3	12
Matilijo Canyon	C-6	11	Rockland Lime and Lumber Co. (see Limekiln Creek [near Lucio])		
McBride Ranch	A-1	6	Royce (see California Aggregates)		
McClellan Ranch	A-1	3	Russian Kilns (see Olema)		
McCroy Ranch	C-1	22	Son Benito Lime Co. (see Hamilton)		
McLoughlin Lithographic Stone	B-3	4	Son Benito Quarries Co. (see Westvaco)		
McPhail	C-1	27	Son Francisco Bay Shell (Ideal Cement; Pioneer Shell; South Bay Dredging; Bay Shell)	B-3	11
Melendy Ranch	C-1	34	Son Jose Cement Co.	B-4	ND
Middle Dom	C-1	7	San Juan Bautista plant and quarry (see Ideal Cement Co.)		
Middle Fork	B-3	17	Son Moteo Creek	B-3	16
Miller Quarry (see Pacific Limestone Products Co.)			San Miguelito	C-6	3
Mindega	B-4	1	Son Vicente Creek	B-5	3
Missile City	C-6	4	Sonto Cruz Lime Co. (see Son Vicente Creek)		
Missian Lime Marl	B-3	20	Sonto Cruz Portland Cement Co. (see Son Vicente Creek)		
Mitchell	B-3	8	Sonto Morgorito	C-5	ND
Mono Creek-Blue Canyon	C-6	10	Santo Morgorito Ranch	C-5	5
Monte Bello Ridge	B-4	2	Schmidt Construction, Inc. (see Missile City)		
Monterey Lime Co. (see Bixby Creek)			Sierra Blanco	C-6	1
Montford	C-4	2	Sierra (Serra) Hill-Little Sur	C-3	4
Moore	A-1	2	Sillocci Quarry (see Hortnell Group)		
Moraga Ranch (Lomo Blanco Lithographic Stone Co.) (see Sierrita Blanco)			Skyline	B-3	24
Margon	C-5	11	Smith Grade	B-5	5
Mount Diablo Lime Marl Co. (see Lime Ridge)			Snell Ranch	B-4	6
Mount Diablo Quarries (see Lime Ridge)			South Bay Dredging Co. (see Son Francisco Bay Shell)		
Mount Horlon	C-1	29	Spreckels Sugar Co. (see Hartnell group; Lime Ridge; Bernal)		
Napo Junction	B-2	3	Spring Valley Ridge	B-3	18
Notividad	C-1	10	Stondard Portland Cement Co. (see Napo Junction)		
Navajo	C-5	6	Stone Corral	C-4	5
Nelson Creek	C-4	3	Sugarloaf	C-1	9
Newsom	C-5	10			
Nipomo	C-5	ND			
Najaqui Canyon	C-6	7			
Noren	B-2	8			
Nye	A-3	1			
Oak Flat	C-5	ND			
O'Hara Ranch (see Westvaco)					

ND—Location not determined

ND—Location not determined

<i>Deposit</i>	<i>District</i>	<i>No.</i>	<i>Deposit</i>	<i>District</i>	<i>No.</i>
Suisun Marble (see Cement Hill)			Warwick Claims (see Wilbur Springs)		
Tassajara	C-3	7	Webb and Mingus Calcite	C-4	1
Tassajara	C-5	4	Webb and Mingus Dalamite	C-4	ND
Thurber Quarry (see Pacific Limestone Products Co.)			Western Limestone Co. (see Holmes)		
Talenas Springs	B-2	1	Westphal Ranch	C-1	33
Tamales Bay (see Inverness Park)			Westvaca	C-1	19
Tamales Bay Shell	B-2	34	Westvaca Chemical Division, Food Machinery and		
Trinidad Mining Co. (see Navaja)			Chemical Corp. (see FMC Corp. under San		
Traut Farm (see Inverness Park)			Francisca Bay Shell; Westvaca)		
Tysan (see Skyline)			Westvaca Chlorine Products Co. (see FMC Corp.		
Underwood	C-1	3	under San Francisco Bay Shell; Westvaca)		
Union Sugar Co. (see San Miguelito)			Wiedemann	B-3	5
Unnamed (near Abbott mine)	A-3	8	Winship (see Mante Bella Ridge)		
Unnamed (near Chesbra Reservoir)	B-4	14	White Waman	A-1	9
Unnamed (near Geyserville)	B-1	2	Wide Awake	A-3	7
Unnamed (near Sunal)	B-3	19	Wilbur Springs	A-3	5
Upper Bird Creek	C-1	15	Willow Creek (see Melendy Ranch)		
Usal	A-2	1	Wright's Ranch	B-4	12
Ventura Cement Co. (see Matilija Canyon)					
Wagner's Park	B-5	8			

ND—Location not determined

PLATE 2

CRYSTALLINE LIMESTONE AND DOLOMITE DEPOSITS OF THE NORTHERN GABILAN RANGE DISTRICT, MONTEREY AND SAN BENITO COUNTIES, CALIFORNIA

By E.W. Hart 1976

EXPLANATION

- SUR SERIES CARBONATE ROCKS**
- Is Limestone
 - d Dolomite
 - Is-d / d-Is Limestone-dolomite mixtures, commonly siliceous
 - c Undifferentiated carbonate rock (limestone and/or dolomite); size may be exaggerated
 - + Indicates presence of other rock types, especially granitic rocks

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DEPOSITS

- 8 A.S. and R.
- 1 Barbee Ranch
- 11 Bardin Ranch
- 14 Bird Canyon Ledge
- 31 Bluecrack Mountain
- 4 Bryan and Pearce-Twamy (Ideal Cement)
- 26 Buzzards Raast
- 30 Cawell-Thompson Creek
- 13 East Gabilan
- 5 Flint-Steinbeck
- 12 Fremont Peak
- 17 Garner-Harris
- 28 Hamiltan
- 6 Harmany Hills
- 25 Hartnell Group
- 20 Kaiser-Harris
- 2 Las Vergeles
- 16 Martin Ranch
- 22 McCray Ranch
- 27 McPhail
- 7 Middle Dam
- 29 Mount Harlan
- 10 Natividad (Kaiser)
- 18 Palmtag-Harris
- 24 Parter
- 23 Paver Line
- 32 Quail Creek
- 21 Reeves Northeast
- 9 Sugarloaf
- 3 Underwood
- 15 Upper Bird Creek
- 19 Westvaca (Hallister)
- 33 Westphal Ranch

- 1/ Described in text
2/ Sedimentary breccia and conglomerate composed partly of Sur Series ls.

MAP A

LIMESTONE, DOLOMITE, AND SHELL DEPOSITS OF THE
COAST RANGES PROVINCE SHOWING REGIONS
(NORTHERN-A, CENTRAL-B, SOUTHERN-C)
AND DISTRICTS

By E. W. Hart
1976

MAP B

INDEX TO MAPS OF COAST RANGES REGIONS

DEPOSITS	EXPLANATION	
	ACTIVE	INACTIVE
Limestone	●	●
Limestone and/or dolomite (mixed or undetermined)	■	■
Dolomite	▲	▲
Extensive areas underlain by carbonate rocks		
Province and regional (subprovince) boundary	-----	
District boundary	□	

1960-1968 period

MAP B

SECTIONIZED TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

MAP C

DEPOSITS AND DISTRICTS OF THE COAST RANGES PROVINCE

Deposit	Location (Sec-T-R-Base)	Deposit	Location (Sec-T-R-Base)	Deposit	Location (Sec-T-R-Base)	Deposit	Location (Sec-T-R-Base)		
NORTHERN COAST RANGES (A)				Northern Santa Lucia Range District, C-3					
Humboldt District, A-1				3. San Vicente Creek (Pacific Cement & Aggregates)					
1. Jolly Creek	13-1N-11-E	1. Lime Ridge (Cowell)	13-17-20-1N-1W-MD	4. Holmes	20-10S-2W	1. Limekiln Creek (near Chualar)	28-16S-4E-MD		
2. Moore	19-19S-2-E	2. Oil Canyon	15-16-1N-1-E	5. Smith Glade	25-10S-3W	2. Bixby Creek	9-16-18S-1-E		
3. McCallum Ranch	5-1N-1-W	3. Grady	10-14-1S-1S-1W	6. Bonnie Doon	25-26-36-10S-3W	3. Bixby Mountain	Mainly 14-15, 23, 25-18S-1-E		
4. Richter	11-1N-1-W	4. Warden Run	35-1N-2-W	7. Cowell Home Ranch	2, 3, 9, 10, 11, 14-11S-2W	4. Sierra (Sierra) Hill	SW 18S-1-E		
5. Hackett	16-1N-1-W	5. Patterson Pass	20-24-2S-1-W	8. Wagner's Park	12 or 11-11S-2W	5. Little Sur	17, 18, 20-18S-4-E		
6. McBride Ranch	26-27-1N-2-W	6. Collier	16-2N-1-E	9. Peasley Gulch	9-15S-2W	6. Pico Blanco	25, 36-18S-1-E; 1, 2, 11, 12-19S-1-E		
7. Johnston	4-9-2N-1-W	7. Mitchell	32-1N-4-E	10. Pacific Limestone Products	11, 14-11S-2W	7. Tassajara	29-19S-4-E		
8. Parkhurst Ranch	23-2N-1-W	8. Canyon	11-34-18S-1-E			8. Horse Canyon	35-19S-5-E; 2, 3-20S-5-E		
9. White Woman	29-4S-1-E	9. Pleasanton	4-5-4S-1-E			9. Coast Ridge (Marble Peak)	19S-2-E; 20S-23-E; 21S-34-E		
Mendocino District, A-2				SOUTHERN COAST RANGES REGION (C)					
1. Udal	1-2-1N-18W	10. San Francisco Bay Shell Deposits (Hidalgo, Panoche, South Bay)	Mainly 3N-4N-3W-4W	Gabilan Range District, C-1					
2. Fisher Ranch	36-22N-13W	11. Rockaway	2-4N-6W	1. Barbee Ranch	9-13S-4E-MD	Parkfield-Coalinga District, C-4			
3. Quinn Ranch	26-17N-14W	12. Highway One	11-4N-6W	2. Los Vegeles	NW 13S-3-E; NW 13S-4-E				
4. Earhart Ranch	2-14N-16W	13. California Aggregates (Eken Royce)	11-4N-6W	3. Underwood	13-13S-4-E				
		14. Pharoah Ranch	12-4N-6W	4. Bryan and Pearce-Twinley (Ideal Cement)	24-13S-4-E				
Clear Lake District, A-3				5. Flint-Stembeck	23-13S-4-E	1. Webb and Mingo Calcite	11-20S-13E-MD		
1. Nye	1-12-18N-6W-MD	15. San Mateo Creek	18-4N-5W	6. Harmony Hills	20-13S-5-E	2. Montford	24-21S-14-E		
2. Daniels	21-18N-6W	16. Middle Fork	19-4N-5W	7. Middle Dam	29-13S-5-E	3. Nelson Creek	22, 23, 26-22S-13-E		
3. Lambert Ranch	20-16N-5W	17. Spruce Valley Ridge	20-29-4N-5W	8. A.S. and R.	28-13S-5-E	4. Little Cholame (Patriquint Stone Corral)	31-22S-14-E; 5, 6-23S-14-E		
4. Clark Mountain	12-14N-7W	18. Linnard Inlet Summit	22-4N-1-E	9. Sugarloaf	25, 36-13S-3-E	5. Liole Corral	25, 36-24S-13-E; 31-24S-16-E		
5. Wilson Springs	W 1/2 14N-5W	19. Mission Line Marl	31-4N-1-E	10. Natividad (Kaiser Aluminum & Chemical)	35, 36-13S-3-E; 2-14S-3-E				
6. Manzanita	29-14N-5W	20. Laid Ridge	2-13S-5W	11. Baird Ranch	33, 34-13S-4-E; 3-14S-4-E	Southern Santa Lucia Range District, C-5			
7. Wide Awake	28 or 29-14N-5W	21. Placerville Creek	11-5N-5W	12. Fremont Peak	35-13S-4-E	1. Lime Mountain	15-16-26S-9E-MD		
8. Unnamed Inlet (Albion mine)	31-11-14N-5W	22. Hilltop	11-5N-5W	13. East Gabilan	36-13S-4-E	2. Dubosi	25-26S-9-E; 30-26S-10-E		
9. Butte Valley	Approx. 14-14N-7W	23. Skylar	12-5N-5W	14. Bird Canyon Ridge	31-13S-5-E	3. Almaden	34-26S-10-E		
10. Capay Valley	10N-11N-3W-10N-2W			15. Upper Bird Creek	6-14S-5-E	4. Tassajara	21, 28-29S-12-E		
CENTRAL COAST RANGES (B)				16. Martin Ranch	28-16-33-13S-5-E	5. Santa Margarita Ranch	28-29S-13-E		
Headlands District, B-1				17. Garner-Harris	34-13S-5-E	6. Navajo	28, 33-29S-16-E		
1. Black Ranch	30-11N-9W-MD	1. Mindego	7-18, 19-7S-3W, 22-7S-4W	18. Palintag-Harris	34, 35-13S-5-E; 3-14S-5-E	7. Aumier and Rodriguez	30-9-30S-14-E		
2. Fremont Inlet (Greyville)	14-10N-9W	2. Monte Bello Ridge	15-7N-4W and SW 1/4 7S-2W	19. Westview (Hollister)	2-14S-5-E	8. Loper Canyon	36-30S-13-E		
3. Headlands Marble	21 or 24-9N-10W	3. Perminite (Kaiser Cement & Limestone Corp.)	17-18-7N-2W	20. Kaiser-Harris	3-4-14S-5-E	9. Kessler	9-16-31S-15-E		
4. Povey Valley	32-10N-5W	4. Kennedy Road	24-8N-1W	21. Reeves Northeast	4-14S-5-E	10. Newton	23 or 24-32S-13-E		
5. Robinson Fork	13-8N-13W	5. Reid	19-8N-2-E	22. McClay Ranch	4-14S-5-E	11. Morgan	36-32S-14-E		
6. Robinson Fork	13-8N-13W	6. Smith Ranch	18-8N-1W	23. Power Line	4, 5, 7, 8-14S-5-E				
North Bay District, B-2				24. Potter	7-14S-4-E				
1. Tolosa Springs	6-5N-2W-MD	7. Fox Gulch Line In	27-8N-1W	25. Hartnell Group	Mainly SW 1/4 14S-4-E				
2. Cement Hill	5-7, 8-5N-1W	8. Lyndon	28-8N-1W	26. Buzzards Roost	16-14S-5-E				
3. Santa Junction	24-4N-4W-29-4N-3W	9. Guadalupe Creek	29-8N-1-E	27. McPhail	13-14S-5-E; 18-14S-6-E				
4. Tomales Bay Shell Deposit	51-16-1N-9W	10. Guadalupe Reservoir	34-8N-1-E	28. Handlin	22-14S-5-E	Santa Ynez District, C-6			
5. Deming's Point	161-9-3N-1W	11. Galen	8-9N-2-E	29. Mount Harlan	22-14S-5-E	1. Sierra Blanca	Mainly SW 1/4 2N-27W and NW 1/4 6N-26W-SB		
6. Brendi	21-3N-9W	12. Wagon C Ranch	16-9S-2-E	30. Cowell-Thompson Creek	30-14S-6-E	2. La Salle-Sloan	11, 12-6N-35W		
7. Inverness Park	34-1N-9W	13. Baldy Ryan	11-9N-1-E	31. Rhinoceros Mountain	25, 26-14S-4-E	3. San Miguelito	18 or 19-6N-34W		
8. Suen	35-1N-9W	14. Unnamed Inlet (Chert) Reservoir	20-9N-2-E	32. Quail Creek	7-15S-5-E	4. Missile City	19, 20-6N-34W		
9. Benito Frontal Works	31-34-1N-3W	15. Castro Valley	15-11S-3-E; 30-11N-4-E	33. Westphal Ranch	10, 11-15S-5-E	5. El Jaro	19, 20, 28, 29, 30, 33-6N-33W		
10. Olema	18-2N-8W			34. Melendy Ranch	21, 27, 28-15S-7-E	6. Alisal	21-6N-31W		
Santa Cruz District, B-5				Panoche Hills District, C-2					
1. Tui	17-10N-6W-MD	1. Marble				7, 18, 19, 20, 29, 30-14S-11E-MD	7. Nojiqui Canyon	25-6N-32W	
2. Ice Cream Grade	13-10N-1W, 18-10N-2W						8. Bee Rock	31-6N-29W	
								9. Los Prietos	11-5N-17W
								10. Mono Creek-Blue Canyon	Mainly 5N-26W
								11. Matija Canyon	22, 23, 24, 25-5N-24W and 19-5N-23W

• • • LIMESTONE IN THE COAST RANGES — BULLETIN 197 — 1978 •

PLATE 1

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