THE OCCURRENCE OF SOME FUSED SEDIMENTARY ROCKS AT
RAVENSWORTH, N.S.W.

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With Plates IX and X.

The occurrences described herein all lie within the Hunter River Valley, a district with which the name of the late Professor Sir T. W. Edgeworth David will long be associated in connection with his survey of its coal resources. It is thought fitting, therefore, that this paper should be included in the volume published in commemoration of the centenary of his birth.

A number of small outcrops of black slag-like material, which closely resembles basalt in appearance, were noted some years ago during the course of the geological survey of the Singleton-Muswellbrook region, and they were tentatively mapped as volcanic necks or minor igneous intrusions.

Upon microscopic examination of thin sections of specimens from these occurrences the rocks proved to be so unlike any basaltic rocks known to the writer that doubts at once arose as to the correctness of their original classification as igneous intrusions. Arrangements were made to visit the locality to study them in the field and to collect further specimens for systematic study.

A close examination of the field association of the outcrops in conjunction with a study of thin sections of further specimens indicates that the slag-like material is the result of fusion of clayshales and sandstones caused by the burning of a coal seam. No positively identifiable igneous material could be found in any of the localities visited.

Occurrences of this type are somewhat rare except in the vicinity of collieries in which the working of the coal seams has caused accidental fires, and descriptions of the effects of such fires on the surrounding rocks are few. The present paper places on record the peculiar types of mineral assemblages and microscopic structures observed to result from the fusion of fairly common sedimentary rocks subjected to the intense heat generated by the combustion of a seam of coal, and also indicates how such occurrences may be distinguished from igneous intrusions. It is obviously of great importance in the survey of coal-bearing sedimentary basins to be able to make this distinction, as the effect of igneous intrusions on underlying seams is likely to have been widespread, whilst the effect of fires is much more localised and can have had little effect on seams of coal lying below the level of the fire zone.

David (1907) noted the fusion of sediments along the burned outcrop of the Greta seam near Cessnock, and stated that the melting had been so complete that he at first mistook the material for contemporaneous basalt. No references, however, are to be found concerning the Ravensworth exposures.

LOCATION OF THE OCCURRENCES.

The principal outcrops of slag are in the vicinity of Ravensworth in the Singleton district, on Portions 150 and 226, Parish Liddell, County Durham. They are all close to the New England Highway, near the overhead bridge crossing the railway line, some three miles north of Ravensworth. Five are on the eastern side of the road a few hundred yards north of the bridge, and a sixth lies about 3/4 mile west of the road, near the site of the old Bayswater Colliery. All lie within an area of two square miles.
They are all within the Tomago beds of the Main Permian Coal Basin and lie some 30 to 50 feet above the Bayswater coal seam, which is exposed nearby in a railway cutting. The enclosing rocks are freshwater shales and sandstones containing thin bands of sideritic material, which on weathering yield beds of concretionary limonite. The sandstones are somewhat clayey and contain some sideritic cement.

The countryside is flat to gently rolling, with little stream erosion, and there is a fairly deep mantle of soil, so that rock exposures are few. The slag outcrops are all small, most of them under 50 feet in diameter, and, as they are harder and more resistant than the surrounding rocks, form the tops of low rounded hills. Neither the exact size nor shape of any one outcrop can be determined, as their margins are hidden by soil. All of them are thin, not more than about 2 feet of material being visible in most of them.

Although the various outcrops have not been accurately levelled, inspection suggests that they all lie on, or nearly on, the same plane and that they are part of a connected whole.

**General Description of the Outcrops.**

In a typical exposure angular fragments of light-coloured, hardened clayshale are to be seen embedded in a black and generally vesicular slaggy matrix, which branches and invades the surrounding sediments. The whole mass has the appearance of a volcanic agglomerate. The shale fragments vary in size from about 6 inches in diameter downwards to pea-sized pieces. They are sharply irregular in shape and show no preferred orientation. They are fairly closely packed and greatly exceed in volume the amount of slaggy matrix. In places the slag is present only as thin stringers an eighth of an inch or less in width invading cracks in the shales. (See Plate X, Fig. 7).

Associated with this agglomerate-like material are sandstones which have been affected by heat, all stages from slight baking, through partial fusion to complete melting, being visible within the space of a few inches. The fusion of the sandstones has yielded a grey vesicular glassy mass in which some white unfused sand-grains are still to be seen, and traces of the original bedding remain even where fusion appears to have been complete. The clayshales and sandstones immediately above any of the fused material have been hardened and have developed a pale pink to terra-cotta-red coloration as a result of heating. The volume of such baked shale and sandstone is greatly in excess of the amount of fused material.

There is no evidence that any of the fusion of the sedimentary material is due to igneous action and abundant evidence to the contrary is present. This contrary evidence may be summarised as follows:

1. No definitely recognisable igneous rock could be detected in any of the exposures.

2. The amount of fused and semi-fused sandstone and baked shale is far greater than is normally to be found surrounding any minor intrusions into sedimentary rocks. In the undoubted doleritic sills and dykes of dolerite in the nearby districts of Muswellbrook and Jerry's Plains, the contact effect on the surrounding sediments is negligible, no fusion at all being visible and only a thin zone of mild "baking" a few inches thick being visible in the surrounding sediments.

3. Specimens of sandstone and shale from the vicinity of the slag outcrops were submitted to fusion tests by heating in a muffle furnace. These specimens were virtually unchanged at 1100°C, the first signs of softening were noted at about 1250°C, whilst marked softening took place only at temperatures in excess of 1350°C, and complete fusion at about 1370°C. These temperatures are well
above those which have been recorded in open volcanic craters and basaltic lava flows, the usual figures for which are quoted as about 1000°C to 1100°C. Such temperatures would therefore not result in the fusion of the sandstones in the area.

(4) The specimens of sandstone and shale heated experimentally all assumed a pale pink or red colour, identical with that of the rocks around the slaggy outcrops. This colour is due to oxidation of iron-bearing minerals under the action of heat, and is similar to that produced in bricks and tiles during firing in kilns. Typically such oxidising conditions are lacking during igneous intrusions and the sedimentary rocks surrounding igneous bodies do not assume a pink or red colour.

(5) At the "Burning Mountain" at Winged some 20 miles N. of Muswellbrook, where a seam of coal is still on fire and has been burning for a period estimated by David (1907) as some centuries, the strata above the burnout seam have assumed the same pink to red coloration as the rocks at Ravensworth. No definite slaggy material, however, is to be seen at Winged, either on account of a more refractory rock-cover to the seam, or to the fact that the seam is burning under a very thick cover, and erosion has not yet uncovered the material immediately over the remains of the seam.

(6) The reddening of sediments over a wide area by the burning of a seam of coal in Wyoming has been described by Bastin (1905), who also noted the presence of fused slaggy material. His description of the occurrence could aptly be applied to the Ravensworth rocks, although the amount of completely fused material in the Wyoming area is far less than here. He described the slag veins in the reddened shales as only 1/16 inch thick, whilst at Ravensworth individual veins are several inches in thickness.

(7) Workings in the Muswellbrook open-cut colliery some 10 miles to the North have exposed portions of the Greta seam which have been on fire, and in which large masses of black, slaggy material have been formed. This material is similar in most respects to the Ravensworth slags. The formation of clinker during the combustion of coal in a furnace is too well known to be worthy of comment, but gives further indication that the heat of combustion of coal is sufficient to melt sedimentary rocks which contain fluxes, principally iron, lime, magnesia and alkalis in amounts which are not uncommon.

It can now be stated beyond all reasonable doubt that the slag outcrops are the result of fusion of sediments by a fierce fire. The fire covered a fairly wide area, as evidenced by the prevalence of reddened rocks. The isolated outcrops of slag may be remnants left by the erosion of a large area, but may represent "chimneys" or fissures through which flames and hot gases escaped from an underlying fire and about which intense heating was localised.

Whether the fire originated in the underlying Bayswater seam cannot be stated in the absence of openings or test borings in the immediate vicinity of the slag outcrops. It is considered, however, in the light of evidence offered by the relatively large area of reddened material, that the heat did not come from an underlying source, but that the outcrops represent the sole remains of a seam which has been completely destroyed by fire and subsequent erosion.

Microscopic Structures in the Slags.

Examination in hand-specimen shows slight variations in colour between different pieces of slags and also differences in the amount of vesicular material present, but microscopic examination reveals the presence of extremely diverse mineralogical assemblages and structures.

The two principal types of slag are: (1) those which can be seen to have been derived from the partial or complete fusion of sandstones, and are still in
the position in which they were formed, and (2) those which have melted completely and flowed into cracks in the more refractory aluminous clayshales. The former are composed chiefly of quartz grains and more or less glass, chiefly dark brown in colour, whilst the latter are finely crystalline and closely resemble basalts.

The fused sandstones might be described as buchites and they bear many resemblances to similar rocks described by Thomas (1922) occurring in xenoliths of sedimentary rocks enclosed by Tertiary intrusives in the island of Mull. The most completely fused ones are composed almost entirely of dark brown glass containing only a few residual grains of badly corroded quartz, many of which are fringed with small, platy crystals of quartz, which have the typical shape of tridymite crystals. These represent actual plates of tridymite formed during the heating of the quartz, which have, on cooling, inverted back to quartz. (Plate IX, Fig. 1).

Many of the specimens of buchite examined show beautifully formed plumose and dendritic crystallites of pyroxene and magnetite, tiny needles of felspar and rare hollow, pseudo-hexagonal very small crystals of cordierite (Plate IX, Figs. 2-4). Mineralogically these rocks are much less complex than the buchites of Mull which Thomas describes as containing, in addition to the above minerals, sillimanite, corundum and spinel, and which he considered to have derived certain constituents by contamination or exchange with the surrounding basalt. Certain specimens contain indefinite spherulitic masses of poorly differentiated material, which so far is unidentified, but which may be mullite.

The finely crystallised slags are far more basic than the buchites and at first sight under the microscope might readily be mistaken for basalts. They are composed largely of a pale green feebly pleochroic pyroxene, with abundant magnetite, some cordierite, tiny needles of felspar and a small amount of dark brown residual glass, in which magnetite, chiefly in the form of skeletal crystallites, is abundant. (Plate X, Figs. 5-6).

The pyroxene is present largely in the form of elongated prisms but equant-shaped grains are also developed. The pale green colour and elongated form are not characteristic of the pyroxene of basalts, but the pyroxene often developed in furnace slags commonly is of this type.

Some of the cordierite is poorly crystallised and closely resembles the nepheline found in many of the Tertiary basalts of eastern Australia, but in some of the specimens the mineral is well-crystallised in short, stumpy prisms averaging about 0·2 mm. in length, and pseudo-hexagonal twins are common. Most of the crystals are colourless, but the largest of them, if favourably oriented in the section, show a pale blue or lilac tint and are markedly pleochroic. Some 'H'-shaped crystallites of cordierite are to be seen in some specimens, and hexagonal hollow box-like forms filled with brown glass are also to be seen.

Felspar needles comprise only 1 or 2 per cent. of the rock. They are very small, averaging less than 0·1 mm. in length and 0·01 mm. in diameter. Multiple twinning is just detectable and extinction angles of up to 20° can be measured, indicating a probable composition of around Ab_{59}An_{50}, a fairly basic andesine.

The basic slag is somewhat similar to some of the Wyoming material described by Thomas, and to some of the sediments fused by igneous action in Scotland and the nearby islands of the West Coast, where the development of cordierite, pyroxene and magnetite has been noted by several writers.

It is unlikely that the basic slag could have been formed from fusion of either sandstone or the typical clayshales of the area, as they are not rich in fluxes and contain insufficient iron to have formed the large amount of pyroxene and magnetite present. The coal seams in the district, however, contain bands
in which siderite and iron pyrites are abundant. These bands are most prevalent near the tops of the seams and during working of the coal are a constant source of danger, as oxidation of the pyrites is a common cause of heating, which has resulted in numerous mine fires. It is considered that fusion of such bands has provided the material for the basic slags, especially as in brickmaking operations using clayshales from both the Wianamatta beds in the Sydney area and from the Coal Measures in the Newcastle district, the presence of sideritic bands gives rise to clinking troubles during the firing of the bricks.

Beds of sideritic material occurring in the clayshales at Ravensworth could have provided the material for the slags, but as no such beds are observable within many feet of the present position of the slags, it is thought that the slags originated within the material of the coal seam itself.

The source of the magnesia in both the cordierite and the pyroxene may possibly be questioned, but the presence of magnesia in the Permian sediments of the district is indicated by the fairly common occurrence of nodular masses of magnesite in the overlying soils.

CONCLUSION.

It is hoped that the foregoing description of the field-occurrence of these basic slags and their mineralogical composition and peculiar micro-structures will be of some assistance in the recognition of similar occurrences elsewhere and will help in distinguishing between basic intrusive rocks and fused basic sediments.

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REFERENCES.


EXPLANATION OF PLATES.

PLATE IX.

Fig. 1.—Plates of tridymite in dark brown glass resulting from fusion of sandstone. Grains of corroded and partially absorbed quartz are to be seen at the lower end of the field. ×120.
Fig. 2.—Plumose crystallites of pyroxene in siliceous glass resulting from fusion of sandstone. ×500.
Fig. 3.—Dendritic crystals of magnetite in light coloured glass resulting from fusion of sandstone. ×500.
Fig. 4.—H-shaped crystallite of felspar in dark brown glass resulting from fusion of sandstone. A corroded grain of quartz surrounded by tridymite can be seen in the bottom left corner of the field. ×500.

PLATE X.

Fig. 5.—The typical "pseudo basaltic" slag consisting of green pyroxene showing well-marked cleavage, cordierite (the light coloured stumpy crystals, tiny felspar laths and small areas of dark brown glass heavily charged with magnetite dust). ×120.
Fig. 6.—Cordierite crystal from the same slide as Fig. 5, showing well-marked pseudo-hexagonal form. ×500.
Fig. 7.—Hand specimen of brecciated light coloured shale traversed by veinlets of black slaggy material. § natural size.

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