ON THE EARTHWORM FAUNA OF THE GREAT AMERICAN DESERT AND ADJACENT AREAS[1]

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The Great American Desert, in long gone days when grade school geography texts were large enough to conceal sundry surreptitious activities from Teacher, was a conspicuous feature on American maps. Little is heard today about that desert and a hasty glance through the present, smaller-sized texts suggests that the region may have lost much of its significance even if it has not entirely disappeared. Deserts usually are not associated mentally with soft-bodied, moisture-loving animals such as earthworms. Nevertheless, some Asiatic, desert-like regions have large populations. Very little information has been available hitherto about the earthworms of the Great Basin and adjacent states. Fortunately, Prof. D E. Beck was interested in this problem and for a number of years collected oligochaetes as opportunity offered. Now that he is no longer able to continue that activity he has interested a former student and colleague, Prof. T. W. Barrett in carrying on the project.

No attempt is made to specify an exact boundary for the region under consideration herein. All of it does have one character in common which will become obvious as this contribution is read. Of California only the arid southern region is included. A small portion of the northwest corner of Idaho is excluded for reasons stated below. Some data about states, for which no specimens were available, are summarized (*cf.* appendix) to complete a review of available evidence pertinent to the problems under consideration.

The introduction originally was as above but the manuscript was not for a time submitted for publication because of anticipated objections to the title and the frequent use of "desert" in the text. Then Hollon's book (1966) was encountered. According to that author, the existence of a great American Desert is a fact that must not be concealed or deprecated. Rather, it should be fully acknowledged, with pride for past achievement in difficult circumstances and with justified hope for future control insofar as available water permits. The approximate limit of desert influence, as shown in Hollon's frontispiece map, encloses most of the region herein discussed. Although not because of inadequate rainfall, Minnesota, Iowa and Missouri are included for reasons explained below.

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ACANTHODRILIDAE

Microscolex Rosa, 1877

Microscolex dubius (Fletcher, 1887)

CALIFORNIA.— San Diego Co.: Alpine, 1836 feet, bottom of canyon, relatively undisturbed area east of city on Route 80, moist humus type of soil at stream bank, March 10, 1966, 0-0-5. Beck; Santa Barbara Co.: Santa Barbara, 2 miles south of city limits, highly granular sand covered with about a quarter inch of humus of stream bank, under Pacific Coast Highway, March 25, 1966, 0-0-2. Beck.

ARIZONA.— Maricopa Co.: Mesa, March 6, 1966, 0-0-5 and 2-0-17. T. Barrett and D E. Beck. Wickenburg, March 8, 1966, along banks of Hassayampa River, March 8, 1966, 0-0-1. Beck.

REMARKS.— *M. dubius* had been reported previously from California but like other earthworm species only from a northern part of the state.

Reproduction is parthenogenetic.

Microscolex phosphoreus (Duges, 1937)?

ARIZONA.— Luminescent specimens (alive) secured by Barrett were considerably damaged during transportation. The spermathecae were like those of *M. phosphoreus*. No other species of the United States is known, at present, to have those two characteristics along with an appropriate size. There is no previous record of the species from Arizona. An older record of *phosphoreus* is for Santa Barbara County, California.

REMARKS.— Reproduction in *phosphoreus* probably is parthenogenetic. Both species of *Microscolex* are widely distributed anthropochores, probably originally from southern South America, certainly exotic anywhere in North America.

LUMBRICIDAE

Allolobophora Eisen, 1874

Allolobophora chlorotica (Savigny, 1826)

CALIFORNIA.— This species was first recorded from California nearly ninety years ago as *riparia*. Less than a quarter of a century later it was simultaneously recorded from 29 places in the state. That presumably was the basis for a subsequent erroneous characterization (Michaelsen, 1900) of the distribution as "ganz Nord-Amerika." Actually to this date, the species has only been reported from about a score of the 49 mainland states and but five of the Canadian provinces.

The species is not now expected to be common in southern California.

Reproduction is obligatorily biparental.

IDAHO.— Idaho Falls, September 2, 1952, 5-16-3. Beck; Canyon Co.: Middleton, from sod below surface of Boise River one mile south of the town, June 19, 1964, 0-0-5. Beck; Clark Co.: Birch Creek, at 6500 feet, about 15 miles south of Lemhi County border, from turf under birch, willow and an occasional quaking aspen, June 3, 1952, 1-2-14. Beck; Lemhi Co.: Salmon, 11 miles to the north, *ca.* 4100 feet, from fibrous root system of grassy turf of a relatively dry meadow near Salmon River, June 1, 1952, 2-3-8. Beck, Mary Clark, Grace Grant.

REMARKS.—*Megascolides americanus* Smith, 1897, of course was the first species to be recorded from within the present political limits of Idaho. The worms were found just east of the Washington border near Pullman. The latter is presumed to be the type locality. The presence of *M. americanus* in Latah County, if not a result of transportation, puts the place where it was found into a Pacific zoogeographic region and thereby removes it, as already mentioned above, from the area under consideration herein.

The records above are the first of an identified megadrile species for a very large unexcluded portion of Idaho. That state is one of those in which Seton (1904 or 1929 summarizing 19th century observations and records) himself could find no earthworms. However, long ago Wilcox (1884) reported that "At Boise City, Idaho, some enthusiastic disciples of Izaak Walton imported and successfully reared the coveted bait in soil suited to the habitat of the Lumbricidae!" The species is unlikely to have been *chlorotica* but certainly does not need to be *L. terrestris* (*q. v.* below) as some are likely to think. The introduction was made, according to Wilcox, because there were no "angleworms" in prairies of the "Northwest."

European settlement began in 1860. Some years probably passed before angleworms were first introduced.

NEVADA.— Elko Co.: Ferguson Springs, ca. 25 miles south of Wendover (Utah) on Route 50, under boards and rocks along edge of drain where seep water from the spring coursed down the hillside, August 5, 1950, 0-0-1. Beck ("Surrounding country extreme desert.") Lyon Co.: Wabuska, July 5, 1966, 4-6-28. Carson River, south of Silver Spring, July 15, 1966, 0-1-1. E. V. Komarek, Sr.; Washoe Co.: Wadsworth, damp porous soil associated with root system of rank plant growth some distance from edge of the Trukee River, August 6, 1950, 0-0-13. Beck.

REMARKS.— These are the first records of earthworms for Nevada. For reasons now unknown, neither Seton (1929) nor Wilcox (1884) mention Nevada although it already had been cut off from Utah as a separate territory in 1861.

UTAH.— Sanpete Co.: Mt. Pleasant, Pleasant Creek Picnic Grounds, at contact line of conifers and aspens, August 5, 1951, 0-0-8. Beck; Summit Co.: Wanship, at 5900 feet, about two feet above stream bed, six inches under sod kept moist by ephemeral

seepage, July 13, 1962, 0-1-2. Beck; Uintah Co.: Vernal, soil by a roadside creek, August 27, 1952, 0-0-1. Beck; Utah Co.: Soldier Summit, upper three inches of heavy clay under cardboard and wooden boxes of an abandoned garbage dump, May 22, 1952, 1-2-10. Provo, April 12, 1951, 0-0-3. Beck; Washington Co.: Pine Valley, July 16, 1953, 0-0-3. Zion National Park, detritus and under stones along one of the side streams near Weeping Rock, Virgin River, September 3, 1950, 0-1-1. Beck.

Remarks.— The records above are the first for Utah of an identified species. However, earthworms probably have been there for at least a century. Provo, Utah, according to Hallock, (1877, p. 353), "is the only place west of the Rocky Mountains where an abundance of earthworms may be had, the species having been introduced by an enterprising physician from the east."

The introduced worms are unlikely to have been of *chlorotica*, as anglers, for several centuries, have deemed them useless as fish-bait. *Lumbricus terrestris* probably was believed, by the enterprising physician, to be his species, but one, or more, of the allolobophoras is much more likely.

Arizona.— Mohave Co.: Cane beds, under rocks in sandy soil with little humus by a trough at which cattle drink, from an area no "more than a yard square," July 1, 1953, 0-1-17. Beck; Yavapai Co.: Prescott, March 7, 1966, 0-6-14. Beck.

Remarks.— *A. chlorotica* had not been recorded hitherto from Arizona, one of the states in which Seton (1929) failed to find earthworms.

Montana.— Mineral Co.: Saltese, 3 miles east of Lookout Pass on Route 10, at about 4000 feet, mucky black forest soil near a small stream and/or a coarse sand and gravel mixture by the stream side, June 25, 1954, 0-0-4. Beck.

Remarks.— This is the first record of an earthworm species for the large state of Montana. Seton (1929) found no earthworms there.

Colorado.— Routt Co.: Along the Yanipa River, *ca.* 2 miles north of Steamboat Springs, under stones, boards, logs and in loose soil near willow clumps in a small meadow, August 27, 1952, 0-0-8. Beck.

Remarks.— This species was recorded from Colorado once before (Smith, 1917) but without specification as to county or town.

In his Colorado searches, Seton (1929) found no earthworms.

Further evidence as to former absence in the state was provided by Cockerell (1924):

"In the mountain district of Colorado, and the adjacent upland plains, it appears that earthworms were formerly absent. Old settlers assure us that when they first came there were none. This seemed at first almost incredible, but in recent years Prof. Frank Smith of the University of Illinois has collected earthworms in Colorado, and found only the widespread presumably introduced types." (*cf.* Smith, 1917)

Cockerell is but one of the very many biologists who have thought the facts to be "almost incredible."

Allolobophora longa Ude, 1885

COLORADO.— Chaffee Co.: Buena Vista, Rancho Sawatch, August 14, 1953, 0-1-0. Ottys Sanders.

REMARKS.— This is the first record of this species for any place west of the Mississippi River.

Allolobophora trapezoides (Duges, 1828)

CALIFORNIA.— Imperial Co.: Holtville, bank of Alamo River west of town, March 9, 1966, 0-0-2. Beck; Kern Co.: Wasco, residence of P. D. Pilsbury, dark wet earth under a hedge around outlet of an air-conditioning hose, August 21, 1950, 4-2-2. Beck. With fibrous root system of Bermuda grass at edge of a stagnant pool in an irrigation ditch, August 21, 1950, 0-1-4-6. P. D. Pilsbury per Beck; Los Angeles Co.: Torrance, six inches of moist organic soil above sand in a flower bed, August 29, 1950, 5-1-1. Beck. Foothills of Angeles Mountains, at *ca.* 1500 feet, December 31, 0-4-8. D. McKey-Fender. Orange Co.: Capistrano, one mile north in ditch by highway, December 29, 0-0-4. D. McKey-Fender. San Bernardino Co.: Victorville, one half mile west of bridge over Mohave River, in wet, coarse sand under algal compost, September 1, 1950, 0-0-3. Beck. Santa Barbara Co.: Santa Barbara, two miles south of city limits on Pacific Coast Highway, very moist, highly granular sand covered with about a quarter inch of humus on bank of stream under highway, March 25, 1966, 0-0-1. Beck. San Diego Co.: Pine Valley, June 21, 1966, 0-0-10. E. V. Komarek, Sr. Alpine, bottom of a shallow canyon, at east entrance to city on Route 80, moist humus soil on banks of small stream. March 10, 1966, 12-9-19. Beck (nine cocoons secured at this site may have been deposited by *A. trapezoides*).

REMARKS.— A deep brown allolobophora, so common at moist or swampy places in California, was mentioned by Eisen in several of his pre-1900 contributions. The species must have been lacking in Scandinavia or he would have had a name for it. Indeed, because of that unfamiliarity he seems at times to have suspected that the species might be native. Much more recently and with much less justification *L. rubellus* has been believed to be native to Washington State merely because of its commonness there.

The two anthropochorous allolobophoras, often correctly characterized as deep brown, are *A. longa* and *trapezoides*. Neither had reached Scandinavia by 1900. Since then *A. trapezoides* has been secured in a northern part of California and once, rather surprisingly, at a height of 5800 feet. No evidence indicative of any California colonization by *longa* has been found. *A. trapezoides* now seems to be originally from a Mediterranean source. As such, the

species could have been introduced at an early date by Spaniards who established 21 missions from San Diego to Sonoma during 1769-1823. The vehicle of transport could have been earth with wine-grape plants which were taken to most if not all of the missions.

Absence of earthworms in middle and southern California also was mentioned in some of Eisen's publications. Seton (1929) found none in the mountains and the dry parts.

Reproduction, in *A. trapezoides*, is parthenogenetic. However in a sperm-maturing, Italian morph embryonic development does not begin until it is initiated by penetration of sperm into the ovum (pseudogamy). Polyploidy (*cf.* Muldal, Omodeo, 1952) has been reported.

IDAHO.— Bannock Co.: McCammon, 3 inches below surface and in an area *ca.* 2 feet square, a few feet from bank of Portneuf River and about a foot above water level,May 30, 1952, 0-1-8. Beck. Butte Co.: Arco, to the south about 1 mile, heavy black clay loam at water's edge and a more loose and only slightly moist soil a few feet above the water's edge, May 31, 1952, 0-2-19. Beck, Mary Clark, Grace Grant. Canyon Co.: Middleton, four inches below surface of an area with sod where logs and other detritus had accumulated near Boise River, June 19, 1954, 0-3-11. Beck. (Some of the worms secured at that site were said to be "balled" and presumably were in diapause. Two couples were copulating and they may have been of the amphimictic species found at the same site, though male sterile individuals do sometimes still copulate with each other. Cocoons were deeper down and in sandy soil.) Fremont Co.: "Osborne Springs," 25 miles north of Ashton on Route 91, in heavy black loam, 6-8 inches below surface and under a thick grass turf but ground dry at surface, September 1, 1952, 0-0-0-6. Beck (The collector stated that the worms were in the process of "balling up.") Kootenai Co.: Worley, upper three inches of soil in grassy woodland area close by a stream, June 24, 1954, 0-1-18. Beck. Latah Co.: Moscow, eight miles to the south, in area surrounding drain-off from cesspool, May 20, 1950, 0-0-1. C. W. Lame. Lemhi Co.: Salmon, hillside seep spring area, on route 93, 1 mile north of town, May 31, 1952, 0-3-16. Beck. 11 miles to the north, *ca.* 4100 feet, from fibrous root system of grassy turf of a relatively dry meadow near Salmon River, June 1, 1952, 0-4-11. Beck, Mary Clark, Grace Grant. Lincoln Co.: Shoshone Falls. Porous black soil, under rocks in shaded grassy areas, near the "Falls" area, June 18, 1954, (10?)-4-12-1. Wet to mucky sites near a spring that is the water supply for the public, June 18, 1954, 0-0-4. Sandy area beneath a west facing cliff, June 19, 1954, 0-1-3. Beck.

REMARKS.— *A. trapezoides* is the second oligochaete species to be recorded herein for the first time from Idaho. In that area Seton (1929) found no earthworms. His conclusion as to absence was supported by Wilcox (1884). *A. trapezoides* is more likely to have been imported to Idaho in the 1880's than *L. terrestris* which at that

time probably had nowhere near reached its present and still limited American range.

NEVADA.— Elko Co.: Ferguson Springs, on Highway 50, under boards and rocks along edge of drain channel where seep water from the spring coursed down the hillside, surrounding country extreme desert, August 5, 1950, 1-3-5. Beck. Lyon Co.: Wabuska, July 5, 1966, 1-1-0. E. V. Komarek, Sr. Washoe Co.: Wadsworth, from damp, porous soil associated with root system of rank plant growth some distances from edge of the Trukee River, August 6, 1950, 0-3-11. Beck.

REMARKS.— *A trapezoides* is the second earthworm species to be recorded herein for the first time from Nevada. Although this state was not mentioned by Seton (1929) he obviously believed (*cf.* p. 144) its earthworm fauna to be the same as that of other desert states.

European settlement began around 1849.

UTAH.— Beaver Co.: Beaver, soil of a peat-like consistency near a small stream, July 11, 1952, 0-1-13. Marvin Coffey per Beck. Wahwah Springs. Moist soil along stream bank, in a marshy soil and under rocks near the marshy area, September 12, 1952, 8-2-0. Highly organic soil and under rocks near edge of desert spring and its runoff, September 12, 1950, 1(+24?)-4-5-1. Beck. Box Elder Co.: Lucin, seven miles to the north at a desert spring where water was salty and vegetation was of the alkaline desert type, June 19, 1952 0-0-3. Beck. Daggett Co.: Willow Creek, at 6000 feet, under plant cover of sage and juniper, near Uintah Mountains, June 12, 1953 0-0-11. Beck. Garfield Co.: Bear Valley Junction (probably August 1952?), 4-4-0. M. A. Coffey per Beck. Iron Co.: Cedar Breaks National Monument, June 20, 1953, 3-6-20-2. Beck. Juab Co.: Levan 8 miles to the south on Route 28, 3-6 inches below surface, under stones and boards in an area about two yards square, April 19, 1952 1 (+?)-20-13-11. Beck. (The area is extremely dry in the summer snow had covered the ground 10 days before the collection.) Piute Co.: Marysvale, 2 miles south of Big Rock Candy Mountain on Route 89, with fibrous root system of grass and sedge quite close to water level in Sevier River, June 26, 1952, 1-0-10. Beck. Rich Co.: Sage Creek Junction, bank of a creek, with wet soil and fibrous roots, at 6500 feet, August 21, 1952, 0-3-14. Woodruff, at the edge of marshland seven miles west and in the confines of a canyon mouth at 7000 feet, six inches below surface in very porous and moist soil June 25, 1953, 0-2-4. Beck. San Juan Co.: Kigalia Ranger Station Bears Ears, in black soil near stream at 8500 feet, June 8, 1955 0-5-22-9 and June 9, 1955, 0-0-2. Bluff, May 5, 1951, 0-1-4. Beck Sanpete Co.: Mt. Pleasant, Pleasant Creek Picnic Grounds, beneath bark and under trees fallen to the ground, August 5, 1951, 3-3-11 Beck. Summit Co.: Wanship, at 5900 feet, about two feet above stream bed. six inches under sod kept moist by ephemeral seepage July 13, 1962. 0-1-1. Echo. July 11, 1952, 0-0-2. Beck. Utah Co Soldier Summit, upper three inches of heavy clay under cardboar

and wooden boxes of an abandoned garbage dump, May 22, 1952, 16-6-2. (Late juveniles had rudiments of genital tumescences in clitellar region but none were recognizable in ix-xi. Tubercula pubertatis unrecognizable.) Lehi, Lehi Sugar Factory area, in wood of a rotted board near pond, April 25, 1952, 1-0-0. Beck. (Elsewhere in the area no worms were found.) Weber Co.: Ogden, depressions in the flood plain plant growth is rank, September 3, 1952, 5(+?)-5 (+?)-0. Beck. Washington Co.: Grafton, upper 8 inches of heavy, sandy, dark-colored loam, under rocks, boards, and logs in an orchard April 5, 1952, 3-3-26. Beaver Dam Wash, Ed Terry Ranch, 3-10 inches below ground surface but under gopher mounds, in alfalfa field, at *ca.* 2500 feet, in the joshua tree-creosote belt, February 23, 1952, 0-17-6. St. George or Springdale, September 2, or September 3, 1950, 0-0-1-2. Pine Valley, July 16, 1963, 0-1-14. Leeds, Oakgrove Campground, at 700 feet, mucky soil along a seep stream, July 14, 1953, (?)-2-4. Zion National Park, in detritus and under stones along one of side streams near Weeping Rock, Virgin River, September 3, 1950, 0-2-2. Beck. Wayne Co.: Elkhorn Ranger Station, Thousand Lake Mt., at 9700 feet, damp, loose black soil under rocks and dead timber, and in a forest of quaking aspen, *Populus tremuloides*, August 9, 1952, 3-2-10. Beck.

Remarks.— *A. trapezoides* is the second species to be recorded herein for the first time from the state of Utah.

The original home of the taxon probably is in some part of the Mediterranean region. Professor Beck was asked to provide information as to how a Mediterranean earthworm could have been brought to Utah. He replied (*in lit.*) that he believed some stock of fruit trees came along with the first settlers as an agricultural program had been worked out even before Mormons left Nauvoo. Arrival in Utah was between 1847 and 1850. So plants started to arrive and were well in growth soon after 1847 and began to be spread by colonization north, south, east and west. Beck, speaking of the history of the settlement of St. George with which he is well acquainted, stated (*in lit.*, Jan. 5, 1965): "Joseph E. Johnson, an early leader in horticulture in southwestern Utah, imported many fruit trees right after settlement. These came by horseback, wagon, buggy, and carried by hand; some from California and others from northern Utah. This was between 1861 and 1870. Within that period the people had no fruit, to a condition of abundance: Peaches, plums, pears, apples, figs, nectarines, almonds, quince, raspberries, strawberries, pomegranates, and apricots. One time he imported 1,000 maple trees hoping to develop the maple sugar industry in southern Utah." Plants presumably were brought across the plains from Mississippi or from Los Angeles by way of the San Bernardino Pass. If winegrape plants were imported from Los Angeles the dark brown allolobophora that was so common in California could have been brought to Utah directly. Another possibility is that the species also could have come along with plants from southern states or even a southern part of Illinois.

Arizona.— Cochise Co.: Alfalfa field, 4 miles north of Elfrieda and *ca.* 25 miles north of Douglas, upper two inches of sandy loam with perhaps 2½% organic matter, September 3, 1966, 18-1-1-15. Leslie Canyon, McNeal, upper four inches of sandy to clay loam with 2-3% organic content, along a small stream (no fishing), under Arizona willow, September 3, 1966, 1-2-3-1. 16 miles northeast of Douglas Canyon-Ricker Road, ¼ mile east of road near cattle pen at 4600 feet, from sod and upper 4 inches of black, heavy, clay loam nearly saturated by four days of rain (no farms and permanent streams in the area), September 16, 1966, 8-1-21. 3 miles south of Junction of Leslie Canyon and main east-west Rucker Canyon road, among roots in top four inches of loam by abandoned water storage tank (for cattle, no fishing streams nearby), September 16, 1966, 5-3-6. Barrett per Beck. Tombstone, Costello Ranch, 8 miles from town at elevation of *ca.* 5000 feet, in soil rich with manure (pH *ca.* 7.5), July 23, 1933, 0-2-6 also 2 fragments, each containing a clitellum. A. Petrunkevich per G. E. Pickford.

Gila Co.: Sierra Ancha Exp. Forest Headquarters. Two miles north of Headquarters, along almost dry Rose Creek, in sandy loam under walnut and oak, August 29, 1966, 0-0-0-9. Ten miles north of headquarters, at confluence of Rose and Workman Creeks, top four inches of sandy-clay loam at edge of meadow, under walnut, sycamore and Arizona willow, at 6200 feet, August 29, 1966, 11-4-0-1. Top 2 inches of loam to sandy loam under or near maple (but not pine and fir), within 10 feet of bank on each side of Workman Creek (but lacking 10-50 feet from the bank), at 6900 feet, August 30, 1966, 6-2-3. A dell under a maple, 3 miles up Workman Creek from Young Road, at *ca.* 6500 feet, sandy loam with maple leaves and grass, September 1, 1966, 9-3-6-3. Barrett per Beck. Mohave Co.: Cane beds, under rocks in sandy soil with little humus by a trough at which cattle drink, July 11, 1958, 0-1-8. Beck.

Remarks.— *A. trapezoides* probably was the member of the *caliginosa* congeries that was recorded from Arizona 67 years ago. Recent collections from the state have contained only one lot of *turgida* and none of *tuberculata*. A very abnormal Tombstone specimen, at first tentatively referred to *caliginosa* (Gates, 1956), enabled synonymization of the supposedly Lusitanian and very old *A. relictus* Souther, 1909, without examination of the type (the only known specimen). The homoeosis of both worms was maximal.

Arizona is one of the states in which Seton (1929) found no earthworms. It is unlikely that he searched in gardens or sites to which the animals could have been deliberately or accidentally introduced.

Montana.— Ravalli Co.: Hamilton, four miles west and near Blodgett Creek at 3600 feet. upper 3-4 inches of black soil mixed with sand under *Pinus ponderosa*, June 1, 1952, 1(+1?)-2-18. Black, heavy loam under coarse sandy soil near bank of Bitterroot River, June 1, 1952, 0-3-2. Beck, Mary Clark, Grace Grant. Victor, moun-

tain meadow stream rising in the Bitterroot Mountains, June 25, 1954, 0-0-6-1. Beck.

Remarks.— No species of earthworm had been reported from Montana before. The state is one of those in which Seton (1929) found no earthworms.

The earliest European settlers, after traders, trappers and explorers, were miners. Farming is said to have been little till after 1880.

Wyoming.— Hot Springs Co.: Wilderness, 20 miles south of Dubois, along bank of Deniwoodie River where it crosses Route 287, under short grass turf at edge of stream, August 30, 1952 (2?)-26-5. Beck. Teton Co.: Teton National Park, about 5 miles north of the park boundary where Snake River crosses Route 287, sodded bank of river (where bait had been dumped at end of day's fishing?), August 31, 1952 (4?)-9-3-1. Beck.

Remarks.— This is the first record of an identified megadrile species from the state of Wyoming. The area is mentioned as one of those in which Seton (1929) could find no earthworms.

Probably few Europeans had settled in Wyoming before 1867 when the Union Pacific began to build its railroad through the state.

Colorado.— Boulder Co.: Longmont, under log in pasture at Boulder Creek and its crossing by Route 287, August 29, 1952, 1-3-2. Beck. Grand Co.: Hot Sulphur Springs, moist loose dark soil with fibrous grass roots along bank of Colorado River about 7 miles southwest of the town, August 28, 1952, 0-0-0-2. Beck. Larimer Co.: Fort Collins, eight inches of dark, compact, sandy loam above water level in seepage area at base of South Reservoir, August 29, 1952, 0-2-2-3. Stonewall Creek, 30 miles south of Wyoming border on Route 287, loose sandy soil with much humus in sodded area where willow growth was rank, August 29, 1952, 0-15-8-2. Beck. Routt Co.: Steamboat Springs, two miles north, along edge of Yanipa River, also under stones, boards, logs, August 27, 1952, 0-1-1. Beck.

Remarks.— These are the first records of *A. trapezoides* for Colorado, a state in which Seton (1929) found no earthworms (also *cf* p. 145).

Gold was discovered in 1850 but the rush came only in 1858. Before that there probably had been little white settlement.

Iowa.— Jefferson Co.: Fairfield, Parsons College, May 22, 1951, 0-0-5. Von Ohlen.

Remarks.— *A. trapezoides* had been recorded for Iowa but as *A. iowana* Evans, 1948. A cotype from the U. S. Nat. Mus. has been examined. The Fairfield specimens mentioned above are from the type locality and were secured by the same person who collected the types of Evans' species.

Allolobophora tuberculata Eisen, 1874

California.— Santa Barbara Co.: Santa Barbara, March 25, 1966, 0-2-1. Beck.

Remarks.— *A. tuberculata* had not been recorded from California previously.

Reproduction, in *A. tuberculata*, is obligatorily biparental.

Idaho.— Canyon Co.: Middleton, four inches below surface of sod where logs and other detritus had accumulated on bank of Boise River, June 19, 1954, 0-0-3. Beck. (Worms were congregated in the humus but cocoons were in sandy soil beneath. Two pair were *in copula*. Although soil still was relatively moist, some worms were "balled." Clark Co.: Birch Creek, about 15 miles south of Lemhi County border on Route 28, from turf under birch, willow and an occasional quaking aspen, at 6500 feet, June 3, 1952, 4-3-8. "Osborne Springs," *ca.* 25 miles north of Ashton on Route 191, heavy black loam, 6-8 inches below surface, in process of "balling," surface quite dry, September 1, 1952, 1-1-3. Beck. Lemhi Co.: Salmon, 11 miles to the north, *ca.* 4100 feet, from fibrous root system of grassy turf of a relatively dry meadow near Salmon River, June 1, 1952, 0-8-11. Beck, Mary Clark, Grace Grant. One mile north, seep area of a hillside spring, 0-4-17. Beck. Morgan Co.: Weber Canyon, 6 miles east of Coalville, heavy loam with humus in shaded woodland down to depth of 8 inches, at 5600 feet, July 11, 1952, 0-1-20. Beck.

Remarks.— *A. tuberculata* is the third species to be recorded herein for the first time from Idaho.

Nevada.— White Pine Co.: Kennicot Duck Creek Station, one mile to the south, wet heavy clay soil with organic matter, August 5, 1950, 0-2-2. Beck.

Remarks.— *A. tuberculata* is the third species to be recorded herein for the first time from Nevada.

Utah.— Cache Co.: Hyrum, north fork of the Blacksmith Fork Canyon, near edge of mountain stream at 7500-8000 feet, under birch and sod, June 27, 1953, 0-5-6. Beck. (From 8-10 inches below surface, in dark compact soil. No worms in top six inches of sandy soil. Some were "balled.") Piute Co.: Kingston, bank of ditch at base of cliff in canyon desert at 6100 feet, June 26, 1-0-2. Beck. Summit Co.: Wanship, at 5900 feet, about two feet above stream bed, six inches under sod kept moist by ephemeral seepage, July 13, 1962, 0-0-1. Beck. Utah Co.: Provo, Brigham Young University campus, January 31, 1966, 0-1-0. Beck.

Remarks.— *A. tuberculata* is the third species to be recorded herein for the first time from Utah. The state was not mentioned by Seton (1929) but he obviously believed its earthworm fauna to be the same as in other desert states, *i.e.*, none.

Montana.— Mineral Co.: Saltese, 3 miles east of Lookout Pass on Route 10, at about 4000 feet, mucky black forest soil near a small stream and/or a coarse sand and gravel mixture by streamside, June 25, 1954, 0-0-2. Beck. Ravalli Co.: Hamilton, nine miles south on Route 93, bank of Bitterroot River, in black layer under sand and turf, June 1, 1952, 0-21-7. Beck, Mary Clark and Grace Grant. Vic-

tor, from grassy roots of a mountain meadow stream, June 25, 1954, 0-0-16. Beck.

REMARKS.— *A tuberculata* is the third species to be recorded herein for the first time from Montana.

WYOMING.— Albany Co.: Laramie, August 29, 1952, 1-2-9. Beck. Fremont Co.: Lander, soil with humus along bank of Papaogie Creek, August 30, 1952, 0-7-1. Beck.

REMARKS.— *A. tuberculata* is the second species to be recorded herein for the first time from Wyoming.

COLORADO.— Chaffee Co.: Buena Vista, Rancho Sawatch, August 14, 1953, 0-0-1. Ottys Sanders. Grand Co.: Hot Sulphur Springs, under stones and in fibrous grass roots of moist, loose, dark soil with much humus along banks of Colorado River, August 28, 1952, 0-3-25. Beck. Larimer Co.: Fort Collins, seepage area at base of South Reservoir, in upper eight inches of a dark, compact, sandy loam high in humus above a wet level, August 29, 1952, 0-14-7. Beck.

REMARKS.— These are the first records of *A. tuberculata* for Colorado.

NEW MEXICO.— Grant Co.: Fort Bayard, Central City, *ca.* 6190 feet, arroyo drainage, 6 and more inches below surface, February 27, 1966, 0-0-2. Beck.

REMARKS.— This is the first record of a lumbricid earthworm for the state of New Mexico.

The first permanent European settlement, by Spaniards, was in 1610.

IOWA.— Jefferson Co.: Fairfield, Parsons College, May 22, 1951, 0-3-4. F. W. Von Ohlen.

REMARKS.— This is the first record of the species for Iowa. The present specimens were secured from the type locality of *A. iowana.* Evans also had specimens of *tuberculata.* He recognized that they were different from the *caliginosa* he had studied in England and that they might be of a new species. The taxon already had been provided a name by Eisen as well as by Friend and Gates, independently.

Allolobophora turgida Eisen, 1874

CALIFORNIA.— San Diego Co.: Alpine, bottom of a shallow canyon, at east entrance to city on Route 80, moist humus soil on banks of small stream, March 10, 1966, 2-5-25. Beck. (Nine cocoons found at the site are less likely to be of *A. turgida* than *A. trapezoides.*) Santa Barbara Co.: Santa Barbara, very moist, highly granular sand covered with about a quarter inch of humus on banks of a small stream, March 25, 1966, 0-0-1. Beck. Mendocino, June 30, 1966, 1(+4?)-1-1. E. V. Komarek, Sr. (Mendocino is the only locality at which *A. turgida* is known to be present along with *A. trapezoides* and *tuberculata.*)

REMARKS.— *A. turgida* had not previously been recorded from California.

Reproduction, in *A. turgida*, is obligatorily amphimictic.

IDAHO.— Bannock Co.: Pocatello, roadside parking and picnic area to south on Route 91, under shubbery and boards in a very moist situation, June 3, 1952, 0-0-7. Beck. Canyon Co.: Middleton, four inches below surface of sod where logs and other detritus had accumulated on banks of the Boise River, June 19, 1954, 0-0-8. Beck. (*Cf.* note on this site, *tuberculata.*) Latah Co.: Moscow, eight miles to the south, in drain-off from a cesspool, May 20, 1950, 0-0-1. C. W. Lame. Lemhi Co.: Salmon, 11 miles to the north, *ca.* 4100 feet, from fibrous root system of grassy turf of a relatively dry meadow near Salmon River, June 1, 1952, 0-2-5. Beck, Mary Clark, Grace Grant.

REMARKS.— *A turgida* is the fourth species to be recorded herein for the first time from Idaho.

NEVADA.— Elko Co.: Ferguson Springs, under boards and rocks along edge of drain channel where seep water from spring coursed down the hillside, surrounding country extreme desert, August 5, 1950, 0-1-3. Beck.

REMARKS.— *A. turgida* is the fourth species to be recorded herein for the first time from Nevada.

UTAH.— Cache Co.: Hyrum, north fork of the Blacksmith Fork Canyon, near edge of mountain stream at 7500-8000 feet, 0-2-9. Beck. (*Cf.* note re site, p. of *tuberculata.*) Morgan Co.: Weber Canyon, 6 miles east of Coalville, heavy loam with humus in shaded woodland, down to depth of 8 inches, at 5600 feet, July 11, 1952, 0-0-2. Beck. Summit Co.: Wanship, at 5900 feet, about two feet above stream bed, six inches under sod kept moist by ephemeral seepage, July 31, 1952, 0-4-16. Beck. Wayne Co.: Elkhorn Ranger Station, Thousand Lake Mt., at 9700 feet, damp loose black soil, under rocks and dead timber, and in a forest of quaking aspen, *P. tremuloides*, August 9, 1952, 0-0-1. Fruita, wet soil near a rock-edge seep only, January 24, 1951, 0-0-2. Beck.

REMARKS.— *A. turgida* is the fourth species to be recorded herein for the first time in Utah.

ARIZONA.— Gila Co.: Sierra Ancha Exp. Forest Headquarters. Ten miles north of headquarters, at confluence of Rose and Workman Creek, top 4 inches of sandy clay loam (with optimum moisture and an abundandce of leaf mold) at edge of meadow, under walnut, sycamore and Arizona willow, at 6200 feet, August 29, 1966, 2-11-0. Barrett.

REMARKS.— *A. turgida* had not been recorded from Arizona.

MONTANA.— Mineral Co.: Saltese, 3 miles east of Lookout Pass on Route 10, at about 4000 feet, mucky black forest soil near a small stream and/or sand and gravel mixture by the stream side, June 25, 1954, 0-0-15. Beck.

REMARKS.— *A. turgida* is the fourth species to be reported herein for the first time from Montana.

COLORADO.—Routt Co.: Along the Yanipa River, *ca.* 2 miles north of Steamboat Springs, under stones, boards, logs, and in loose soil

near willow clumps in a small meadow, August 27, 1952, 0-0-1. Beck.

REMARKS.— This is the first record of *A. turgida* from Colorado.

Bimastos Moore, 1893

Bimastos parvus (Eisen, 1874)

NEVADA.— Lander Co.: Austin, 25 miles west on Route 50, marshland coursing through desert valley, wet organic material, August 6, 1950, 1-0-2. Beck.

REMARKS.— *B. parvus* is the fifth species to be recorded herein for the first time in Nevada.

Reproduction, in *B. parvus*, is parthenogenetic and at least in male sterile morphs obligatorily so.

WYOMING.— Fremont Co.: Lander, 44 miles south, Sweetwater River crossing of Route 287, under old spruce log at sand bar, August 30, 1952, 0-0-5. Beck. Teton Co.: Moran, Teton National Park, under stones and logs, August 30, 1952, 0-0-3. Beck.

REMARKS.— *B. parvus* is the third species to be recorded herein for the first time from Wyoming.

Large populations of *parvus* have not been found anywhere. Known series are short. Long thought to be native to North America, the original home of the species is unknown.

B. parvus, the only known North American anthropochore, has been carried all around the world. More than 67 years ago (Michaelsen, 1900) the species already had been intercepted at San Francsico on plants from China. A later interception (Michaelsen, 1910) was at Hamburg on plants from Japan. Recent interceptions at American ports, were from soil with plants originating in Taiwan, Japan, Australia, Mexico, England, and Italy. The species also had been found in Tibet, Afghanistan, Kazakstan, and St. Paul's Rock (uninhabited by man) in the Indian Ocean. The distribution as now known would seem to indicate that transportation of the species from this country to other continents and then back and forth around the world has been much more frequent than carriage within the United States and has resulted in many more successful colonizations.

Dendrobaena Eisen, 1874

Dendrobaena octaedra (Savingny, 1826)

COLORADO.—Boulder Co.: Boulder, Bluebell Canyon, under moss near spring, September 1914, 0-0-2, (U. S. Nat. Mus.) E. J. Miller. Boulder City, June 18, 1966, 1-0-3-2. L. Krummholz & W. Osburn per Beck. Chaffee Co.: Buena Vista, Rancho Sawatch, August 14, 1953, 0-0-2. O. Sanders.

REMARKS.— *D. octaedra* was recorded for Colorado once before (Smith, 1917) and from Boulder. Reproduction, in *D. octaedra*, is

parthenogenetic and at least in male sterile morphs obligatorily so. Polyploidy has been reported.

NEBRASKA.— Custer Co.: Custer, black soil near creek, June 29, 1946, 0-0-1. J. L. Macnab per D. McKey-Fender.

REMARKS.— *D. octaedra*, previously unreported from Nebraska, is the eighth species to be recorded from that state. Others are: *A. caliginosa*, *B. parvus*, *E. foetida*, *Pheretima diffringens*, and three diplocardias of uncertain status.

Dendrobaena rubida (Savigny, 1826)

IDAHO.— Butte Co.: Arco, to the south about 1 mile, heavy black clay loam at water's edge and a more loose and only slightly moist soil a few feet above the water's edge, May 31, 1952, 0-0-2. Beck, Mary Clark, Grace Grant.

REMARKS.—*D. rubida* is the fifth species to be reported herein for the first time from the state of Idaho.

Reproduction, in *D. rubida*, at least for male sterile morphs is amictic. Amphimixis seems to be optional in sperm maturing morphs. Polyploidy has been reported. Only male sterile morphs were recognized in desert states.

NEVADA.—Eureka Co.: Eureka, 10 miles east, 6500 feet, heavy clayey soil near a mountain spring, August 6, 1950, 0-1-8. Beck.

REMARKS.— *D. rubida* is the sixth species to be reported herein for the first time from the state of Nevada.

UTAH.— Box Elder Co.: Lucin, at a desert spring, seven miles to the north, where water was salty and vegetation was of the alkaline desert type, June 19, 1952, 0-0-1. Beck. Clark Co.: Birch Creek, June 3, 1952, 0-0-1. Beck. Juab Co.: Tom's Creek, Callao, moss at stream side, August 12, 1953, (18?)-0-4. Beck. San Juan Co.: Kigalia Ranger Station, Bears Ears, June 9, 1955, 4-9-3. Beck. Sanpete Co.: Mt. Pleasant, Pleasant Creek Picnic Grounds, beneath bark and under fallen trees at contact line of aspen and conifers, August 5, 1951, 0-0-9. Beck. Summit Co.: Echo, July 11, 1952, 0-0-3. Beck.

REMARKS.— *D. rubida* is the fifth species to be reported herein for the first time from Utah.

WYOMING.— Fremont Co.: Wilderness. 20 miles south of Dubois, in moist soil with much humus, under short grass turf at edge of Deriwoodie River, August 30, 1952, 0-0-7. Beck. Teton Co.: Teton National Park, about 5 miles north of the park boundary where Snake River crosses Route 287, sodded bank of river (where bait had been dumped at end of day's fishing?), August 31, 1952, 0-0-1. Moran, river bank and bed about five miles to the east, August 30, 1952, 0-0-5. Beck.

REMARKS.— *D. rubida* is the fourth species to be recorded herein for the first time in Wyoming.

Elsewhere, in the region now under consideration, *D. rubida* has been reported from Colorado (Smith, 1917) but under another name and without specification as to county or town.

Eisenia Malm, 1877

Eisenia foetida (Savigny, 1826)

California.— Los Angeles Co.: Temple City, March 1957. 0-4-1. P. W. Oman. San Bernardino Co.: Fontana, March 1953, 7-1-12. G. E. Templeton per E. W. Price. March 1957, 3-4-2. P. W. Oman. San Diego Co.: Jacumba, March 9, 1966, 0-8-34. Beck. (Purchased from a bait dealer who obtained them from West Virginia. In this resort city no earthworms were found in the vicinity of the hot springs, near a lake, and other spots in and around the town. Local anglers informed Beck that there are no earthworms locally.)

Remarks.— Previous Californian records of *E. foetida* were all from a northern part of the state.

Reproduction, in *E. foetida*, is obligatorily amphimictic.

Utah.— Utah Co.: Provo, April 12, 1951, 0-1-0. Beck.

Remarks.— *E. foetida* is the sixth species to be reported herein for the first time from the state of Utah.

The single specimen may have been an escapee from an artifical habitat such as the bed of an earthworm farm, a greenhouse, a potted plant, a sewage bed.

Arizona.— Maricopa Co.: Tempe, March 4, 1966, 0-0-55. Beck. (Purchased from an earthworm farm. The species was being sold for bait to produce mulch for gardens, also for introduction into wormless areas to enrich the soil.)

Remarks.— *E. foetida* had not been recorded previously from Arizona. If presence in artificial habitats such as greenhouses and earthworm farms is to be counted the species will have to be recorded from every one of the 50 states with the possible exception of Alaska, as *E. foetida*, under one or more of its popular names, has been sold for cultivation in every state and Canadian province, and was recently introduced to Hawaii. Although sold in large numbers throughout the country and transported back and forth, records for natural habitats are lacking for many states.

Eisenia rosea (Savigny, 1826)

California.— Kern Co.: Wasco, with fibrous root system of Bermuda grass at edge of a stagnant pool in an irrigation ditch, August 21, 1950, 0-0-1. P. D. Pilsbury per Beck. Los Angeles Co.: Torrance, slightly damp ground at edge of water of a marsh, August 29, 1950, 2-9-5, and 6 inches of moist organic soil above sand in a flower bed, August 29, 1950, 10-0-1. Beck. San Diego Co.: Pine Valley, June 21, 1966, 0-0-45. E. V. Komarek, Sr.

Remarks.— *E. rosea* is now reported for the first time from southern California. There are older records for a northern part of the state.

Reproduction, in *E. rosea*, is parthenogenetic and at least for the many male sterile morphs obligatorily so.

IDAHO.— Bannock Co.: McCammon, 3 inches below surface and in an area *ca.* 2 feet square, a few feet from bank of Portneuf River and about a foot above water level, May 30, 1952, 0-0-3. Idaho Falls, September 2, 1952, 5-2-12. Beck. Butte Co.: Arco, to the south about 1 mile, heavy black clay loam at water's edge and a more loose and only slightly moist soil a few feet above the water's edge, May 31, 1952, 0-0-3. Mary Clark, Grace Grant and Beck.

REMARKS.— *E. rosea* is the sixth species to be recorded herein for the first time from Idaho.

NEVADA.— White Pine Co.: Kennicot Duck Creek Station, one mile to the south, wet, heavy, clay soil with organic matter, stream side, August 5, 1950, 2-1-6. Beck.

REMARKS.—*E. rosea* is the seventh species to be recorded herein for the first time from Nevada.

UTAH.— Beaver Co.: Beaver, soil of a peat-like consistency near a small stream, July 11, 1952, 1-1-0. Beck. Piute Co.: Kingston, bank of ditch at base of cliff in desert at 6100 feet, June 26, 1952, 0-2-6. Beck. Rich Co.: Sage Creek Junction, stream bank of a creek, only with wet soil and fibrous grass roots, at 6500 feet, August 21, 1952, 1-0-0. Beck. Sanpete Co.: Mt. Pleasant, August 5, 1951, 0-0-1. Beck. Summit Co.: Wanship, at 5900 feet, about two feet above stream bed, six inches under sod kept moist by ephemeral seepage, July 13, 1952, 0-1-1. Beck. Utah Co.: Soldier Summit, upper three inches of heavy clay under cardboard and wooden boxes of an abandoned garbage dump, May 22, 1952, 0-0-1. Beck. Washington Co.: St. George, almost pure clay at edge of an irrigation ditch from Virgin River, September 2, 1950, 5-0-0. Zion National Park, detritus and under stones among one of the side streams, near Weeping Rock, Virgin River, September 3, 1950, 0-2-3. Beck.

REMARKS.— *E. rosea* is the seventh species to be recorded herein for the first time from Utah.

ARIZONA.— Cochise Co.: 16 miles northeast of Douglas on Leslie Canyon-Rucker Road, ¼ mile east of road near cattle pen at 4600 feet, from sod and upper four inches of black, heavy clay loam nearly saturated by four days of rain (no farms and permanent streams in the area), September 16, 1966, 7-0-1. Three miles south of junction of Leslie Canyon and main, east-west Rucker Canyon Road, along roots and in top four inches of sandy to gravelly clay loam by abandoned water storage tank (for cattle, no farms and fishing streams nearby), September 16, 1966, 40-1-3. Barrett per Beck. (Remote and infrequently visited areas without streams, no fishing streams near sites.) Tombstone, Costello Ranch, at elevation of *ca.* 5000 feet, in soil (pH 7.5) rich with manure, July 23, 1933, 0-0-15. A. Petrunkevitch per G. E. Pickford. Leslie Canyon, McNeal, upper four inches of sandy to clay loam along a small stream (no fishing), under Arizona Willow, September 3, 1966, 6-0-0-3. Barrett. McNeal, March 19, 1966, 2-0-0. Barrett per Beck. Coconino Co.: Payson, June 29, 1966, 4-1-3. Barrett per Beck. Gila Co.: Sierra Ancha Exp. Forest

Headquarters. Two miles north of the Headquarters along almost dry creek in sandy loam, under walnut and oak, August 29, 1966, 1-0-0. Ten miles north of Headquarters, at confluence of Rose and Workman Creeks, at edge of meadow, under walnut, sycamore and Arizona Willow, at *ca.* 6200 feet, August 29, 1966, 1-0-0-1. Top 2 inches of loam to sandy loam with 4-5% organic matter, under maple (but not pine and fir), within 10 feet of bank of Workman Creek (none in region 10 to 50 feet from bank), at 6900 feet, August 30, 1966, 2-1-0. Barrett. Maricopa Co.: Gila Bend, March 8, 1966, 8-3-0. Beck. Wickenburg, March 8, 1966, 6-1-0. Tempe, March 5, 1966, 0-14-19. Barrett and Beck. Mesa, March 6, 1966, 6-6-5-1 + one tail piece and 0-2-1. X. Frost, Beck. March 4, 1966, 0-2-1. Beck. Mohave Co.: Littlefield, rich soil with about 50% humus, under bridge on Route 91 over Beaver Dam Creek, Septemper 2, 1950, 6-5-2. Beck. (The only species secured at the site where worms "were not too numerous and required diligent searching" to find these.) Pima Co.: Tucson, June 18, 1966, -13-0 + 17 tail pieces, Beck. (At least 12 specimens were early adolescents *i.e.*, aclitellate.) June 18, 1966, 7-0-17. E. V. Komarek, Sr. Santa Clara Co.: Sondita Creek, Patagonia, June 19, 1966, 0-1-3. E. V. Komarek, Sr.

Remarks.— *E. rosea* already had been collected in the state before 1900. Nevertheless, Arizona is one of the states in which Seton (1929) said he could find no earthworms.

Spaniards could have brought live plants to their missions from some time in the early 1600's.

Montana.— Mineral Co.: Saltese, 3 miles east of Lookout Pass on Route 10, at about 4000 feet, mucky, black forest soil near a small stream or in a coarse sand and gravel mixture by the stream side, June 25, 1954, 0-0-1. Beck.

Remarks.— *E. rosea* is the fifth species to be recorded herein for the first time from Montana.

Wyoming.— Fremont Co.: Lander, soil with humus along banks of Papaogie Creek, August 30, 1952, 0-0-1. Beck.

Remarks.— *E. rosea* is the fifth species to be recorded herein for the first time from Wyoming.

Colorado.— Larimer Co.: Fort Collins, August 29, 1952, eight inches of dark, compact, sandy loam above water level in seepage area at base of South Reservoir, August 29, 1-0-10. Beck. Routt Co.: Along the Yanipa River, *ca.* 2 miles north of Steamboat Springs, under stones, boards, logs, and in loose soil near willow clumps in a small meadow, August 27, 1952, 0-0-5. Beck.

Remarks.— These are the first records of *E. rosea* for Colorado.

New Mexico.— Chaves Co.: Rio Felix, south of Dexter, February 25, 1966, 0-40-0. Beck.

Remarks.— This is the second species to be recorded herein for the first time from New Mexico. This is one of those states in which Seton (1929) himself could find no earthworms.

The first permanent white settlement was by the Spanish in 1610.

Eiseniella Michaelsen, 1900

Eiseniella tetraedra (Savigny, 1826)

California.— Kern Co.: Deep Creek, Mojave desert, April 25, 1943, 0-0-2. per D. McKey-Fender. Wasco, residence of P. D. Pilsbury, dark wet earth under a hedge and around outlet of an air-conditioning hose under a hedge, August 21, 1950, 0-0-3. Beck. With fibrous root system of Bermuda grass at edge of a stagnant pool in an irrigation ditch, August 21, 1950, 0-0-1. P. D. Pilsbury per Beck. Santa Barbara Co.: Santa Barbara, March 25, 1966, 0-0-3 and 1 tail piece. Beck. San Bernardino Co.: Victorville, one-half mile west of bridge over Mojave River, in wet, coarse sand under algal compost, September 1, 1950, 0-0-1 (Hercynian morph). Beck.

Remarks.— These are the first records of *E. tetraedra* for the southern part of the state.

Reproduction, in *E. tetraedra*, is parthenogenetic and often is obligatorily so because of male sterility. Although male sterile morphs of many species had been studied and named by oligochaetologists, the sterility for long was not even suspected. Megadrile parthenogenesis was first proved experimentally in *E. tetraedra* by raising isolated hatchlings to maturity in the laboratory.

Idaho.— Butte Co.: Arco, to the south about 1 mile, heavy black clay loam at water's edge and a more loose and only slightly moist soil a few feet above the water's edge, May 31, 1952, 2-1-16. Beck, Mary Clark, Grace Grant. Canyon Co.: Middleton, four inches below surface of an area with sod where logs and other detritus had accumulated near Boise River, June 19, 1954, 0-0-1. Beck. Clark Co.: Birch Creek, *ca.* 15 miles south of Lemhi County border, wet to moist sand and under stones at stream's edge, at 6500 feet, June 3, 1952, 0-0-1. Beck. Custer Co.: Challis, several miles to the south, at *ca.* 6500 feet, moist to wet soil and under rocks at side of a small mountain streamlet, May 31, 1952, 20-12-52. Mary Clark, Grace Grant, Beck. Kootenai Co.: Worley, under logs and other debris at bank of a stream that ran into a marsh land, June 24, 1954, 1-4-13. Beck. Lemhi Co.: Salmon, 11 miles to the north, *ca.* 4100 feet, from fibrous root system of grassy turf of a relatively dry meadow near Salmon River, June 1, 1952, 0-0-1. Beck, Mary Clark, Grace Grant. Hill side seep spring area, on Route 93, 1 mile north of town, May 31, 1952, 0-0-2. Beck. Lincoln Co.: Shoshone Falls, beneath rocks at edge of pools, streams and springs, June 19, 1954, 0-0-24. Beck.

Remarks.— *E. tetraedra* is the seventh species to be recorded herein for the first time from Idaho.

Nevada.— Lyon Co.: Wabuska, July 5, 1966, 0-0-25. E. V. Komarek, Sr. Ormsby Co.: Carson River, south of Silver Spring, July 5, 1966, 0-0-20. E. V. Komarek, Sr. White Pine Co.: McGill, drain north of a swimming pool which is northwest of the town, August 5, 1950, 1-1-4. Beck. Kennicot Duck Creek Station, one mile to the

south, at stream edge, wet heavy clay soil with organic matter, August 5, 1950, 1-2-23. Beck.

REMARKS.— *E. tetraedra* is the eighth species to be recorded herein for the first time from Nevada.

UTAH.— Beaver Co.: Wahwah Springs, September 12, 1952, moist soil along stream bank, and under rocks near the marshy area, 5-0-12, under rocks near edge of desert spring and its run-off, 0-0-3. Beck. Box Elder Co.: Lucin, seven miles to the north, at a desert spring where water was salty and vegetation was of the alkaline desert type, June 19, 1-0-0. Beck. Washington Co.: Zion National Park, at 6000 feet, under plant cover of sage and juniper, near Uintah Mountains, June 12, 1955, 0-0-1. Beck. Piute Co.: Marysvale, 2 miles south of Big Rock Candy Mountain on Route 89, with fibrous root system of grass and sedge quite close to water level in Sevier River, June 26, 1952, 0-1-15. Beck. Rich Co.: Randolph, abundant along bank of Otter Creek, at 6600 feet, August 21, 1952, 0-0-9. Beck. Sanpete Co.: Mt. Pleasant, Pleasant Creek Picnic Grounds, at contact line of conifers and aspens, beneath bark and under fallen trees, August 5, 1951, 0-0-9. Beck. Utah Co.: Mt. Nebo, at 8600 feet, under stones, logs, boards near a bog on north side of mountain on the Loop Road, September 21, 1952, 0-0-15. Lehi Sugar Factory Area, in wood of a rotted board near pond, April 25, 1952, 0-0-1. Beck. (Elsewhere in the area no worms were found.) Washington Co.: St. George, almost pure clay at edge of an irrigation ditch from Virgin River, September 2, 1950, 1-0-6. Beck.

REMARKS.— *E. tetraedra* is the eighth species to be recorded herein for the first time from Utah.

MONTANA.— Mineral Co.: Saltese, 3 miles east of Lookout Pass on Route 10, at about 4000 feet, mucky black forest soil near a small stream or in a coarse sand and gravel mixture by the stream side, June 25, 1954, 0-0-1. Beck. Ravali Co.: Hamilton, four miles west and near Blodget Creek at 3600 feet, upper 3-4 inches of black soil mixed with sand under *Pinus ponderosa*, June 1, 1952, 1-0-0. Beck.

REMARKS.— *E. tetraedra* is the sixth species to be recorded herein for the first time from Montana.

WYOMING.—Carbon Co.: Spring Creek, 2 miles south of Saratoga on Route 130, June 7, 1961, 0-0-2, (Hercynian morph). North Brush Creek, 1 mile west of Medicine Bow Natural Forest Line on Route 130, June 7, 1961, 0-0-1. G. F. Edmunds & W. L. Peters. Fremont Co.: Lander, sandy soil near Papaogie Creek at south side of city park, August 30, 1952, 1-1-11 (of which 1-1-8 are of Hercynian morphs). Beck. Yellowstone National Park. September 1, 1952, 0-0-5. Beck.

REMARKS.— *E. tetraedra* is the sixth species to be recorded herein for the first time from Wyoming.

COLORADO.— Chaffee Co.: Buena Vista, Rancho Sawatch, August 14, 1953, 0-0-6. Ottys Sanders. Grand Co.: Hot Sulphur Springs, under stones along edge of Colorado River south and west of the

town about seven miles, August 28, 1952, 0-4-38 (0-4-32 of the Hercynian morph). Beck. Larimer Co.: Fort Collins, August 29, 1952, eight inches of dark, compact sandy loam above water level in seepage area at base of South Reservoir, 2-0-0. Beck. Routt Co.: Along the Yanipa River, *ca.* 2 miles north of Steamboat Springs, under stones, boards, logs, and in loose soil near willow clumps in a small meadow, August 27, 1952, 0-0-5 (1 of Hercynian morph). Beck. Summit Co.: Frisco, one mile to the northeast, August 13, 1953, 0-0-2. Ottys Sanders.

Remarks.— These are the first records of *E. tetraedra* for named Colorado localities. The species was recorded (Smith, 1917) for the state but without specification as to county or otherwise.

South Dakota.— Lawrence Co.: Spearfish Creek, 0.8 miles south of hydro plant no. 2, June 9, 1961, 0-0-1. G. F. Edmunds & W. L. Peters.

Remarks.— Although earthworms are known to have been present in South Dakota for some years (*cf.* Taylor, 1924) the record above is the first in print for an identified species.

Dakota, according to Seton (1929), had no earthworms. The northern state probably had little European settlement till after 1862. First European settlers, other than traders and trappers, arrived in the southern state in 1850.

Taylor stated that earthworms "do not thrive in acid soils such as are found in the great plains section of North America . . . . They are generally plentiful in silt soils along streams . . . . The most productive soil I have ever planted was full of them, always was, and is today. The only fertilizer it ever gets is silt from over-flow of the river, and the same land has been farmed for over seventy years."

The soil of 1,310 square miles in 6 counties of eastern South Dakota is unusually interesting. The average depth is 36 inches in an area with an east-west width of 16-32 miles and a north-south length of 75 miles. Because that soil consists almost entirely of worm casts and filled worm channels it was named (Buntley & Papendick, 1960) Vermisol. Worm activity had almost completely destroyed horizontal zonation.

Like Darwin (in the title of his last book, "The formation of vegetable mould through the action of worms") Buntley & Papendick presumably expected us to deduce that worms = earthworms as they did not once use that word. A request for information brought the following reply (Buntley, *in lit.* Oct. 18, 1960), "I did collect some worms from each of the two worm-worked soils. These were identified as *Lumbricus terrestris* by our entomology department."

European settlement in South Dakota began after 1850. Less than a hundred years (*cf.* Gates, 1966) was probably available for the destruction, by earthworms, of soil zonation to an average depth of three feet. At first that does seem like too much to expect even of

the kind of animals so highly praised by organic gardeners. *L. terrestris*, according to Olson (1928, p. 59), "has become widely distributed over Ohio in the last ten years." Such spreading capacity presumably could enable the required Dakota distribution through a much smaller area in less than a hundred years. However, the identity of the species involved is by no means certain. Far too often, even today, *Lumbricus terrestris* is THE earthworm. Conversely any earthworm easily becomes *L. terrestris*. Within the last twelve years, *Eisenia foetida* and *Allolobophora tuberculata* have appeared as *Lumbricus terrestris* in scientific journals, probably also *A. trapezoides* and *longa* and one or more other megadrile species the identity of which cannot even be guessed.

Evidence supporting a rapid rate of zone-destruction by earthworms may be unpublished in field notes of various pedologists. Between the spring of 1958 and 1961, according to K. K. Langmaid (*in lit.*), Head of Canadian Soil Survey, soil horizons (at a Carlingford, New Brunswick, cut-over forest site) had been obliterated by earthworm action, to a depth of six inches. The species in the sample from that site were *Allolobophora tuberculata* (4 specimens), *Lumbricus terrestris* (1).

The Dakotas unfortunately were not visited by Beck. From the northern state two species have been recorded, *Eisenia foetida* from earthworm farms, *Microscolex phosphoreus* from a greenhouse. Nothing at all is known about megadrile populations of natural habitats.

Lumbricus Linnaeus, 1758

Lumbricus castaneus (Savigny, 1826)

IDAHO.— Lemhi Co.: Bitterroot River, near continental divide on Route 93, June 1, 1952, 0-0-1. Beck.

REMARKS.— *L. castaneus* is the eighth species to be recorded herein for the first time from Idaho. The species appears to be much less important in the western faunas of the United States (*cf.* below). In central Maine, on the contrary, *castaneus* is fairly common but *rubellus* is rarely found.

Reproduction, in *L. castaneus*, is obligatory biparental.

Lumbricus rubellus Hoffmeister, 1843

IDAHO.— Fremont Co.: "Osborne Springs," *ca.* 25 miles north of Ashton on Route 191, heavy black loam, 6-8 inches below surface, in process of "balling," surface quite dry, September 1, 1952, 3-3-4. Beck. Lincoln Co.: Shoshone Falls, damp porous black soil, under rocks in grassy area and 2-8 inches below surface of soil, June 18. 1954, 0-0-1.

REMARKS.— *L. rubellus* is the ninth species to be recorded herein for the first time from Idaho.

Utah.— Weber Co.: Ogden, depressions in the flood plain where plant growth is rank, September 3, 1952, 0-0-2. Beck.

Remarks.— *L. rubellus* is the ninth species to be recorded herein for the first time from Utah.

Colorado.— Routt Co.: Along the Yanipa River, *ca.* 2 miles north of Steamboat Springs, under stones, boards, logs, and in loose soil near willow clumps in a small meadow, August 27, 1952, 1-1-10. Beck.

Remarks.— This is the first record of *L. rubellus* for Colorado.

Reproduction, in *L. rubellus*, is obligatorily amphimictic.

Lumbricus terrestris L., 1758

Idaho.— Bannock Co.: Pocatello, June 3, 1952, 0-0-1. Beck. Latah Co.: Moscow, Palouse soil in lawns of University of Idaho, March 15, 1950, 0-0-2. C. W. Lame.

Remarks.— *L. terrestris* is the tenth species to be recorded herein for the first time (by its scientific name after a definite identification) from Idaho.

Writing about "night crawlers," Painter (1942) said, "Many people in Twin Falls, Idaho get night crawlers for bait from lawns by electricity. The worms supposedly had been imported originally from the East." Night crawler is a common name for *Lumbricus terrestris*. Nevertheless, use of that common term is no guarantee that an identification as *terrestris* would be correct. The fact that electricity was used to secure the worms itself is a contra-indication. Night crawlers, when conditions are favorable, feed and copulate on the surface at night where they are easily "jacked," without electricity, by those familiar with their habits. Millions are easily collected that way every year in this country. If conditions are unfavorable for surface activity, the crawlers are likely to be too deep down to be brought out by a superficial electric current. American allolobophoras, on the contrary, are not known to feed on the surface at night. They are geophagous and more likely to be active at soil levels where they could be stimulated by electricity.

Utah.— Morgan Co.: Weber Canyon, at 5600 feet, about 6 miles east of Coalville, July 11, 1952, 0-0-1. Beck. Summit Co.: Wanship, at 5900 feet, two feet above stream bed, six inches under sod kept moist by ephemeral seepage, July 13, 1962, 4-0-1. Beck. Utah Co.: Provo, April 12 or May 13, 1951, 0-0-1. Beck. Washington Co.: Pine Valley, July 16, 1953, 0-0-2. Beck.

Remarks.— *L. terrestris* is the tenth species to be recorded herein for the first time from Utah. The paucity of records above, surprisingly, may be due to the commonness and usefulness of the species. Beck remembers watching in the fall of 1925 "jacking" of night crawlers in the long practiced manner. By that time the species must have been common around Provo at least. Today, Beck reports, along the highways of the state one sees numerous signs signifying night crawlers for sale. He also mentioned that " jacking"

still is a nightly summer activity unless a fastidious lawn owner has treated his grassland with Pax or chlordane.

COLORADO.— Grand Co.: Hot Sulphur Springs, moist, loose dark soil with fibrous grass roots along back of Colorado River about 7 miles southwest of the town, August 28, 1952, 9-0-1. Beck. Routt Co.: Along the Yanipa River, *ca.* 2 miles north of Steamboat Springs, under stones, boards, logs and in loose soil near willow clumps in a small meadow, August 27, 1952, 1-0-3. Beck.

REMARKS.— *L. terrestris* was recorded from Colorado once before (Smith, 1917) but without specification as to places or sites from which the worms were obtained.

IOWA.— Jefferson Co.: Fairfield, Parsons College campus, May 22, 1951: Mud flats of a small stream on north side, 1-0-1. Wooded slope southwest of flats, 2-0-0. F. W. Von Ohlen.

REMARKS.— Reproduction, in *L. terrestris*, is obligatorily biparental.

Octolasion Oerley, 1885

Octolasion cyaneum (Savigny, 1826)

COLORADO.— Larimer Co.: Stonewall Creek, 30 miles south of Wyoming border on Route 287, loose sandy soil with much humus, in sodded area where willow growth was rank, August, 1952, 0-0-1. Beck.

REMARKS.— This is the second trans-Mississippi record of the species which is but rarely found anywhere in the American hemisphere.

Reproduction, in *O. cyaneum*, is obligatorily parthenogenetic. Polyploidy has been reported.

Octolasion tyrtaeum (Savigny, 1826)

IDAHO.— Butte Co.: Arco, to the south about 1 mile, heavy black clay loam at water's edge and a more loose and only slightly moist soil a few feet above the water's edge, May 31, 1952, 0-0-1. Beck, Mary Clark, Grace Grant.

REMARKS.— *O. tyrtaeum* is the eleventh species to be recorded herein for the first time from Idaho.

Reproduction, in *O. tyrtaeum*, is obligatorily amictic. Male sterility is common. Polyploidy has been reported.

UTAH.—San Juan Co.: Elkhorn Ranger Station, Thousand Lake Mt., at 9700 feet, damp, loose black soil, under rocks and dead timber and in a forest of quaking aspen, *P. tremuloides*, August 9, 1952, 0-0-1. Beck.

REMARKS.— *O. tyrtaeum* is the eleventh species to be recorded herein for the first time from Utah.

COLORADO.— Chaffee Co.: Buena Vista, Rancho Sawatch, August 14, 1953, 0-0-1. Ottys Sanders. Larimer Co.: Stonewall Creek, 3 miles south of Wyoming border on Route 287, loose sandy soil with much

humus, in sodded area where willow growth was rank, August 29, 1952, 0-1-16. Beck

Remarks.— Early settlers, according to Cockerell (1924), maintained they found no earthworms in mountainous districts or in adjacent upland plains of the state.

D. tyrtaeum was reported once from Colorado, as *O. lacteum*. The same author (Smith, 1917) recorded for the state the following valid species: *A. chlorotica*, *D. octaedra* and *rubida*, *E. tetraedra*, *L. terrestris*. Except for *D. octaedra* which had been taken only at Boulder, no data as to counties, sites and number of specimens was provided.

Nebraska.— Laurence Co.: Hickman, June 11, 1960, 0-0-3. W. R. Murchie.

Remarks.— *O. tyrtaeum* previously had not been recorded from Nebraska, even as its synonym, *O. lacteum*.

Species previously reported from th state are seven: *A. caliginosa* (now known to have been a complex of four or more species), *B. parvus*, *E. foetida*, *Pheretima diffringens*, and three diplocardias of uncertain status. The single record of *P. diffringens*, soil near University greenhouses at Lincoln, probably is indicative of the way this oriental species reached the state.

"Settlement began in a small way in 1854," according to P. W. Gates (*in lit.*) but increased considerably after 1862 when a Federal Homestead Act provided free land for veterans.

Iowa.— Sioux Co.: Ireton, under maple trees in yard near farmhouse, 5 miles from the village, April 21, 23-3-25. Mary M. Jinks.

Remarks.— *O. tyrtaeum* was recorded in 1948 from Iowa as *O. lacteum*. Other megadrile records for the state are: *Sparganophilus eiseni* (a North American endemic that is widely distributed), *Allolobophora trapezoides*, *A. caliginosa* (probably *A. turgida*), *Eisenia foetida* and *rosea*, *Lumbricus terrestris*, and *Octolasion cyaneum*.

There was, according to historian P. W. Gates (*in lit.*), "Not much settlement before 1836-1938."

Megascolecidae

Pheretima Kinberg, 1866

Pheretima hawayana (Rosa, 1891)

California.— Los Angeles Co.: Los Angeles, lawn, June 1955, a number of clitellate individuals. A. W. Bell.

Remarks.— Reproduction, in *P. hawayana*, probably is obligatorily amphimictic. The original home of the species is in eastern Asia.

Pheretima hupeiensis (Michaelsen, 1895)

Utah.— Utah County: Provo, Brigham Young University campus, January 31, 1966, 0-2-14. Beck.

REMARKS.— *P. hupeiensis* is the twelfth species to be recorded herein for the first time from Utah. The species had been recorded previously from Louisiana but nowhere else west of the Mississippi River.

The following information about this species was provided by Beck (*in lit.*, June 20, 1966): Each spring and fall and at periods of warmth, which occurred in January of this year, these worms crawled from the lawns by the thousands to the sidewalks, creating quite a squishy situation for the students walking back and forth from the buildings.

Reproduction, in *P. hupeiensis*, is parthenogenetic, probably often because of male sterility.

Directly or indirectly, the species may have come from China.

OCNERODILIDAE

Ocnerodrilus Eisen, 1878

Ocnerodrilus occidentalis Eisen, 1878

This species has been reported occasionally from the desert region. Types were found in California and of course the species was thought to be native to that state. Somewhat later, specimens from China and Hawaii, were intercepted at San Francisco. They were obtained from soil with potted plants. Presumably the species had been transported around the world for several centuries. Even today, the original home of *O. occidentalis* is unknown. Central Africa and tropical America have been postulated.

Absence of specimens in recent collections may be of little or no significance. However, colonization could have been temporary. Similar failures to achieve permanent domicle are believed to have occurred in the faunas of oceanic islands such as Hawaii and St. Helena.

Reproduction is parthenogenetic.

APPENDIX

No collections were available for several states that need consideration herein. Some of Professor Beck's collections were lost in transit which is much regretted because of our ignorance of earthworm faunas.

KANSAS.— Earthworms originally were lacking in Kansas according to Wilcox (1884). There was little European settlement till 1851. By 1917, Smith was able to report three species of *Bimastos*, *parvus*, another now known as *tumidus*, and *welchi*, known only from the original description based on sections of the single type. The latter, according to Smith, was immature. None of the three are native to Kansas. A specimen of a double-tailed worm from Kansas (Harnly, 1932) was said to be of *Lumbricus terrestris* but that too often, even today, means nothing more than "earthworm."

Oklahoma.— Earthworms were lacking in the prairies of Indian Territory according to Wilcox (1884). Since 1954 the following were reported from Oklahoma, *Allolobophora caliginosa* (most probably in large part if not wholly, *A. trapezoides*), *Eisenia foetida* and *rosea*, each of which is present in desert states, *Bimastos tumidus* (the original home of which is unknown), and four diplocardias of uncertain status, three of which were not reported from Missouri and Arkansas.

Minnesota.— *Lumbricus terrestris* was the first earthworm recorded (Smith, 1917) for Minnesota but as usual without data to localities and number of specimens. Mickel (1925), who studied earthworm parasites, provided a little information. *A. caliginosa* was the most abundant earthworm at St. Paul. *L. terrestris* was the second most abundant. *E. foetida* was found only in compost and then not commonly. Mickel's *caliginosa* is less likely to have been *trapezoides* than *tuberculata* or *turgida* or both. Except for those parasites, presence of *L. terrestris* would be the extent of our knowledge of the earthworm fauna of Minnesota in 1967. Each Minnesota species is present in the desert states.

Missouri.— The megadrile fauna of this state comprises the following: *Allolobophora caliginosa* (perhaps in part not *A. trapezoides*), *chlorotica* and *trapezoides*, *Bimastos heimburgeri* (of uncertain status), *tumidus* and *zeteki*, *Dendrobaena rubida*, *Eisenia foetida* and *rosea*, *Eiseniella tetraedra*, *Lumbricus rubellus* and *terrestris*, *Octolasion tyrtaeum* of the *Lumbricidae*, *Pheretime agrestis* of the Megascolecidae, *Sparganophilus eiseni* and 5 diplocardias of uncertain status four of which also are recorded from Arkansas.

Nine of those species are present in desert states, 10 obviously are exotic. Original homes of the diplocardias, species of *Bimastos* and *S. eiseni* are unknown but now seem unlikely to have been in Missouri.

Arkansas.—Megadriles recorded for this state are: *A. caliginosa* (probably in large part, if not all, *A. trapezoides*), *Bimastos parvus* (in which *beddardi* and *longicinctus* may have to be included), *tumidus* and *zeteki*, *Dendrobaena octaedra* and *rubida*, *Eisenia foetida*, *hortensis* (recorded as *B. venetus*), and *rosea*, *Eiseniella tetraedra*, *Lumbricus rubellus* and *terrestris*, *Octolasion tytraeum*, *Pheretima californica*, *diffringens* and *hupeiensis*, four diplocardias of uncertain status.

Eleven of those species are present in desert states. Thirteen obviously are exotic, and three pheretimas being of Asiatic origin, the others of European origin. Species of *Bimastos*, as well as one diplocardia, are unlikely to have originated in Arkansas.

Discussion

A sample of little more than 2500 worms may seem too small to warrant discussing the megadrile fauna of an area containing more than a million square miles. As a result, mainly of the activity of

Prof. Beck, we do know much more about the earthworms of the desert area than before. Each of the following pairs indicates number of species previously and now known from the mentioned states. Arizona 3-8, California (southern part only) 1-7, Colorado 6-12, Idaho (one small section excluded) 0-11 (with no exclusion, 1-12), Iowa 8-8, Montana 0-6, Nebraska 7-8, Nevada 0-13, New Mexico 0-2, North Dakota 2-2, South Dakota 0-1, Utah 0-12, Wyoming 0-6. Numbers of species known from adjacent states are: Kansas 3, Oklahoma 8, Minnesota 3, Missouri 19, Arkansas 20.

Number of species now known from desert states is 21, larger than the number recorded for anyone of the adjacent states with much more rainfall (*cf.* Table 1).

Every one of those 21 species obviously is exotic in the area, most of the lumbricids having come from Europe, one probably from somewhere east of the Mississippi, and megascolecids from Asia. The original home of the ocnerodrilid is unknown, but is unlikely to have been in North America. Prof. Beck has found absence of endemics in such a large area hard to believe, as will many others.

Exotics could have gotten to the desert region in two ways. The first of course is by migration. This is the view of some Europeans (*cf* Omodeo, 1963). European species moved across the north Atlantic to Greenland, Iceland and eventually to the American mainland. There, they alone survived the great glaciations that pauperized, perhaps permanently, the megadrile fauna of North America. Geologists seem to be unaware of proof that an Atlantic bridge existed at the proper time (*cf.* Wright & Frey, 1965). Survival of soft-bodied, moisture-loving animals through countless millenia on bare nunataks seems unlikely.

The other way by which the exotics could have gotten to desert states is by introduction. That is likely to have resulted only from human activity. Supporting evidence for introduction is of two sorts. Data of the first sort got into print as a direct result of the publication in 1881 of Darwin's last book, "The formation of vegetable mould through the activity of worms." Parenthetically it is well to note that the worms are earthworms. The conditions Darwin thought resulted only from megadrile activity existed in the great plains of Canada where there were then no earthworms. Seton (1929) concluded his study of the subject in the following words:

"Since 1882, I have made personal investigations in parts of Saskatchewan, Alberta, Southeastern British Columbia, Dakota, Wyoming, Montana, Idaho, Colorado, New Mexico, Arizona, and the mountains and dry parts of California: and made numberless inquiries covering the western part of the Mississippi drainage, as well as all the adjoining mountains without hearing of any earthworms excepting in localities where they were introduced. (They have recently appeared in many highly cultivated parts of Manitoba.)"

"Further, I am satisfied that, excluding the narrow humid belt along the Pacific Coast, earthworms are not native to any part of

America south of the Great Slave Lake, or west of the immediate Mississippi Valley. Probably the true earthworm is not native to any part of North America." (Presumably by "true earthworm" was meant *L. terrestris*.)

As further support for Seton's conclusions, his "narrow humid belt along the Pacific coast" is where Eisen found endemics unrelated to those of any other section of the United States. A northern portion of that same belt is where Macnab and McKey-Fender were finding endemics until their research was abandoned. Also according to Repenning (1966), "The Pacific Coast Province has remained a more or less isolated faunal unit since the early part of the mammalian history."

Presence of lumbricid exotics in other parts of the world, where endemics could be expected but were lacking, usually was blamed on native inability to survive competition. Those ideas were summarized by Stephenson (1930, p. 905) as follows. "The Lumbricidae are a recently evolved and dominant group which possesses great powers of adaptation to new surroundings. Numerous species have been carried by man and have established themselves all over the world. Their introduction into a new territory frequently causes the disappearance of the endemic earthworm fauna." The Lumbricidae no longer can be regarded as recently evolved, the range from the Mississippi River across Europe and Asia to Japan is the largest of any megadrile family and must be of considerable age. Furthermore, when pending revisions are completed American endemics will not be in the same genera as now are the European species. Nor is the family as a whole characterized by great powers of adaptation and dominance. A few species, perhaps less than a dozen, in the struggle for existence during Quaternary glaciation, may have acquired some unusual colonizing ability but at the same time lost any ability they may have previously had to maintain themselves in tropical climates except at high elevations. Many years ago G. E. Hutchinson collected 268 earthworms (Gates, in MS) in the vicinity of Naples, Italy, where considerable endemicity could be expected, but 240 belonged to the very species that colonized the Great American Desert. Seemingly, European endemics in their own home, lack dominance and marked ability to survive whatever may have been involved.

Anthropochorous forms very clearly have replaced endemics in many niches of various regions in Australia, New Zealand, South Africa and southern South America. By "replaced" nothing more need be understood than "taken the place of." In some of such niches, hemerophobic endemics may have disappeared as a result of human disturbance of their environment before arrival of the supposed competitors. Innumerable cases of transport and of first appearance of worms in a new area around farm houses and fields prove that exotics are hemerophilic and at least do tolerate considerable human interference with their environment. In New Zealand, Lee (1961) thinks replacement rather than competitive extermina-

tion was involved. Miller *et al.* (1955) say that exotics usually appear some years after disappearance of the endemic fauna.

A Washington State endemic, according to Altman (1936), was common in cultivated fields. As he had only ten specimens of the species, the cited observation may have been given him by some one unfamiliar with common similarities of many species. McKey-Fender (*in lit.* March 4, 1948) as a result of her experiences believed that "The natives quickly disappear under cultivation, being restricted almost entirely to the edges of fields or to uncultivated areas . . . . Old timers remark about their disappearance. In recent years, Ray Albright of Dayton, Oregon has noted them most often at the borders of his fields."

In South Africa, according to Pickford (1937), "The apparent displacement of endemic by peregine species in cultivated grounds is probably due to the fact that many of the latter can tolerate conditions which are inimical to the former, for example the continued breaking up and drying out of the soil." Pickford also mentioned instances of South African endemics coexisting, in uncultivated sites, with the exotic lumbricids.

In southwestern Australia, Michaelsen (1907) found that *A. caliginosa* had acquired a wide distribution and had become numerous near towns within seventy years of the first settlement by Europeans. Accordingly, the same lumbricids could have had time enough (*cf.* previous pages), since first European settlements in desert states, to acquire their present distribution. These instances are cited in part because some have thought (*cf.* Omodeo 1963) that far too little time since 1500 A.D. had been available for European species to acquire their present American distributions.

Earthworms are soft bodied animals without exoskeletal protection against dehydration. Water constitutes around 80 percent of body weight in *P. hupeiensis*, *A. caliginosa* (Grant, 1955), *A. chlorotica* and *L. terrestris* (Roots, 1956). Mechanisms for resisting dessication would seem to be of special survival value in the desert. A weight loss of 54 percent by cocoons of *Bimastos zeteki* did not prevent normal development (Murchie, 1960) when water was added. Similar ability often is imputed to other megadriles, especially in popular writings, but experimental proof is lacking. Earthworms of various species can survive a loss of 50-70 percent of their body water. Among those studied was *A. caliginosa* which Grant (1955) found to have the most efficient mechanism for resisting dessication. The American section of the *caliginosa* complex comprised three distinct species each of which could have differed from the others in such a mechanism. Which species was used in the experiments unfortunately is unknown. *A. trapezoides* is the species most frequently obtained in the desert states but is unlikely to have been consistently available in New England.

How much moisture is needed for normal earthworm activity and reproduction? Answers were first sought from precipitation data.

TABLE: Precipitation

State	Rainfall in inches	Remarks
Arizona	3.1 to 32.4	
Arkansas	48.64 (normal)	
California (southern)	10-20 or 0-10	
Colorado	17	7-60
Idaho	8-25	
Iowa	31.44	
Kansas	27	
Missouri	40.15	
Montana	10.15	Or 20 in northwest and on mountains
Nebraska	12.65-27.58	But dry years in irregular cycles
Nevada	3-12	
New Mexico	14.3	
North Dakota	14-22	
Oklahoma	16.51-46.53	
South Dakota	14-24	
Utah	5-40	Latter only in Wasatch Mts.
Wyoming	14.79	6 in parts, to 35 on mountains

Figures are from state articles, Encyclopedia Britannica, (1965). Some authors gave only a single annual state average. Others gave annual averages for smaller regions.

"The average annual rainfall is one of the most important factors delimiting distribution of earthworms," according to Pickford (1937) whose studies were made in South Africa. There she found that endemic acanthodrilines were almost entirely restricted, in the south, by the 20 inch isohyet. In the north, localities of her native worms were bounded by the 30 inch isohyet. Pickford was most interested in the endemics and provided little information as to relationship between rainfall and distribution of the exotic lumbricids. Mention was made of the fact that exotics had been found in areas with less than 20 inches of annual rainfall. Seven lumbricid species (Gates, in MS) were represented in her collections. Each of those species is present in our desert states.

In Manchuria, Kobayashi (1940) found that an annual rainfall of less than 400 mm (*ca* 16 inches) was unfavorable to earthworms. He likewise was mainly interested in native taxa. "In the region where the amount of annual rainfall is less than 400 mm, no endemic species can exist." (p. 308). Some at least, if not all, of the supposed endemics, when revised, will fall, into synonymies of more or less widely spread anthropochores. Probably no single megadrile will prove to be autochthonous (evolved in, and not found elsewhere) in either Manchuria and Mongolia.

Beck collected earthworms in various areas where average annual rainfall is much less than 16 inches and indeed, may amount only to 3-10 inches annually. Surprisingly, the species represented in the desert region by the third largest number of specimens is *E. tetraedra*. This form rarely is found away from water and usually is charac-

terized as amphibious, limnic, hygrophile or as a dweller in purely aquatic habitats. Obviously something more than annual rainfall must be involved.

Check of habitat data reveals that more than half of the desert earthworms (all species) were obtained from banks of creeks, rivers, springs, from seepage areas, marshes, and similar sites. Many other specimens for which site data are lacking, possibly, if not also probably, were from similar habitats. The common factor of each of those habitats is presence of more moisture than would be provided by the annual rainfall. Important and suggestive data were provided for one locality by Barrett. He found the worms in a strip of land ten feet wide, on each side of the creek. In soil 10-50 feet from the creek bank worms were absent.

A monthly rainfall of 11-22 inches in certain sections of Burma completely fails to keep many species from going into a state of hibernestivation (Gates, 1961). Annual averages of rainfall may then be of little or no significance in some desert areas. If so, amount of moisture in soil will determine earthworm survival. Involved will be maintenance of adequate soil moisture for a period long enough to permit completion of a life cycle. Little information is available about life cycles in different climates but in Europe information is being acquired about moisture factors and earthworm survival.

In Hungary, Zicsi (1958) found that individuals of *A. caliginosa* are active only when water content of the soil is at or above 30% of capillary capacity. Four or more species have been involved in the European section of the *caliginosa* complex. Similar figures for validly defined species present in America were, *rosea* 35 percent, *chlorotica* 40 percent, *tyrtaeum* (as *lacteum*) 30 percent.

Parthenogenesis usually is thought to favor colonization of new areas (*cf.* Muldal, 1952) as only one specimen is needed. However, a single specimen of an obligatorily amphimictic individual also can start a new colony—after its battery of spermathecae has been charged with sperm (millions?) as a result of copulating with another individual. Of the 21 species living in the desert states, 12 reproduce parthenogenetically. The other 9 are obligatorily amphimictic. Of the 2500+ individuals, over 1800 were of parthenogenetic species. Less than a third were of amphimictic species. Parthenogenesis has not enabled lumbricids to colonize tropical lowlands. Other factors, such as efficiency of drouth resisting mechanisms, may be of equal or even greater importance especially in desert regions.

If earthworms were absent in plains and desert states when settled by Europeans, the species now known to be domiciled there must have been introduced and, for most of the region, within the last 100-120 years. But how much reliance is to be placed on Seton's observations? Considerable, according to Wilcox (1884) who confirmed and even added to them. Introduction could have been accidental or deliberate. Very many if not most may have been accidental (*cf.* p. above), in soil or other materials around roots of

imported plants. Some introductions were deliberately made in order to have a supply of bait for angling. Reports of deliberate introduction (*cf.* p. 144) provide additional support for previous absence of angleworms. Probably only a very few of the deliberate introductions got reported in print elsewhere.

Some reluctance to accept Seton's conclusions completely might be in order. Travellers have reported absence of earthworms in certain parts of the tropics or adjacent areas. Observations were made in the dry season when the soil was sun baked almost to brick hardness. Worms were estivating at the proper depths in the soil from which they return when the surface became satisfactorily moist. In some Asiatic deserts earthworms remain inactive during drouths of several years. It is of course possible that Seton and Wilcox did make some of their observations in wrong seasons or that they did not investigate inaccessible areas where conditions might have been more favorable. However, Beck's collection provided confirmation. Seton's wording "west of the immediate Mississippi Valley" might also be acceptable if we knew how far west is meant by "immediate." If an eastern part of Texas, some portions of Oklahoma and Arkansas are "imbediate" that is where endemics are now expected.

Before the recent ice ages, lumbricid earthworms probably were widely spread throughout much of the northern hemisphere. Quaternary ice sheets thousands of feet thick exterminated all earthworms for varying distances south of the present pole, in Europe and Asia as well as in America. Evidence proving that extant endemics migrated north in America since recession of the ice is lacking, though such migration frequently must have been assumed. Earthworm extermination was not confined to glaciated portions of Canada and United States. For as yet unknown distances below the southern ice face, the climate was too frigid for earthworms. The very few American lumbricids that did survive, except for *B. parvus*, appear to have little colonizing ability. A few European species, including those now domiciled in the desert states, not only survived, perhaps in nearest proximity to the ice, but even evolved a physiology better adapted to colonizing Iceland, Greenland, Siberia, than tropical lowlands.

Providing an explanation for absence of earthworms in unglaciated portions of the Great Basin states, now seems likely to be more difficult. Until unquestioned endemics are found there, it is necessary to suppose that these animals never lived there or were exterminated, before arrival of Europeans, by unfavorable climatic factors.

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