DEPARTMENT OF THE INTERIOR
Hubert Work, Secretary

U. S. GEOLOGICAL SURVEY
George Otis Smith, Director

PROFESSIONAL PAPER 147

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

1926

W. C. MENDENHALL, CHIEF GEOLOGIST

WASHINGTON
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[The letters in parentheses preceding the titles are those used to designate the papers for advance publication]

ILLUSTRATIONS

A COMPARISON OF THE GENERA METAPLACENTICERAS SPATH AND PLACENTICERAS MEEK

By John B. Reeside, Jr.

In a recent examination of a considerable suite of specimens from the Western Interior of the United States belonging to the Cretaceous ammonite genus *Placenticeras* Meek the writer made comparisons of the species from the Interior with those from the Cretaceous of the Pacific coast ordinarily designated *Placenticeras pacificum* J. P. Smith, *P. californicum* Anderson, and *P. sanctaemonicae* Waring. The two groups of species differ widely in their characteristics, though each is a fairly homogeneous assemblage in itself. It was the writer's intention to propose a new name for the group of *P. pacificum*—indeed, one was proposed and in type, when the publication by Spath[1] of the name *Metaplacenticeras* met the need adequately, and that name is of course used here. Spath's name is based on the citation of Smith's original figure and a notation that *Metaplacenticeras* differs from *Placenticeras* in its falcoid ribbing and distinct suture line. Inasmuch as there has been some divergence of opinion as to the scope and probable derivation of the genus *Placenticeras*, based on the study by different writers of members of one or the other of the two groups, the writer has thought it worth while to record his observations and deductions and to give a fuller account of the new genus.

Smith[1a] investigated the young stages of the species *pacificum* and on the basis of his findings expressed the opinion that *Placenticeras* as represented by it was derived through *Hoplites* from *Cosmoceras*. He found the second, third, and fourth lobes of the adult suture to arise from the subdivision of the first lateral lobe of the primitive suture shown in the very early stages and the first lateral lobe of the adult to arise as a marginal lobe dividing the primitive first lateral saddle. Douvillé[2] had already placed the genus in the Hoplitidae on the basis of similarity of the early sutures to that of *Hoplites*, interpreting the first, second, and third lateral lobes of the adult *Placenticeras* as direct descendants of the primitive first lateral lobe and homologous to the trifid first lateral lobe of *Hoplites*. Hyatt[3] later interpreted the ontogeny of *Placenticeras meeki* Böhm (=*P. whitfieldi* Hyatt, *P. placenta* (DeKay) of Meek, the type of the genus) as not showing any real relationship with *Hoplites*. He considered the first and second lateral lobes of the adult suture as derived from marginal lobes of the primitive first lateral saddle and only the third lateral lobe of the adult as a lineal descendant of the first lateral lobe of the early suture. Pervinquière[4] doubted the generic identity of the forms examined by Smith and Hyatt because of the very marked differences between *P. pacificum* and *P. californicum*, on the one hand, and *P. meeki*, *P. intercalare*, and other typical species, on the other, though accepting both groups as descended from *Hoplites*. Sommermeier[5] attempted to reconcile the divergent views by interpreting the suture as showing a small lobe dividing the primitive first saddle, two adventitious lobes arising on the siphonal flank of the primitive first lateral lobe as forming the first and second lateral lobes of the adult, and only the third adult lobe as being a direct descendant of the primitive first lateral lobe. He considered the primitive second lateral lobe to be variable and in *P. pacificum* to exceed the first lateral in length and become the large fourth adult lobe, whereas in *P. meeki* it is relatively small. The sutures in this view are therefore essentially the same and prove a generic identity. He suggests as another possibility that the sixth adult lobe is really the primitive second lateral lobe and that the fourth and fifth adult lobes are adventitious.

The writer examined the inner whorls of typical individuals of the species *pacificum* Smith and *meeki* Boehm. He found that he could add nothing to Smith's description of the young of the first species and agrees with it entirely. For the second species

[1] Spath, L. F., On new ammonites from the English chalk: Geol. Mag., vol. 63, p. 79, 1926.

[1a] Smith, J. P., The development and phylogeny of *Placenticeras:* California Acad. Sci. Proc., 3d ser., vol. 1, pp. 181–231, 1900.

[2] Douvillé, Henri, Classification des cératites de la Craie: Soc. géol. France Bull, vol. 18, p. 288, 1890.

[3] Hyatt, Alpheus, Pseudoceratites of the Cretaceous: U. S. Geol. Survey Mon. 44, p. 192, 1903.

[4] Pervinquière, Léon, Études de paléontologie tunisienne, Céphalopodes des terrains secondaires, p. 197, 1907.

[5] Sommermeier, L., Die Fauna des Aptien und Albien im nördlichen Peru, Pt. I: Neues Jahrb., Beilageband 30, pp. 319–321, 1910.

several interpretations are plausible. Hyatt's figures [6] of isolated early sutures of *P. meeki* agree with those found by the writer at the same stages, and Hyatt's interpretation may well be true. However, a more complete series such as that figured in Plate 1 of this paper permits a somewhat different and equally plausible explanation. Apparently the first of the three large adult lateral lobes is a marginal of the primitive first lateral saddle, and the second and third are divisions of the primitive first lateral lobe. The fourth adult lateral lobe is the second primitive lateral lobe. The writer could detect no sculpture on the whorls below 6 or 7 millimeters, though Hyatt found faint ribs. At about 10 millimeters obscure rounded radial folds and sigmoid striae are present. At greater diameters only striae were seen. Whatever interpretation of the suture is accepted, it is not very strongly suggestive of *Hoplites*.

The development of the suture is strikingly different from that found in the species *pacificum* Smith and combined with the persistent difference in sculpture is sufficient to put the two series of forms into different genera—perhaps even into different families. Smith's specimens are strongly ornamented from even the very early stages throughout their growth and have for a time a very distinct median keel in addition to the ventrolateral keels. At certain stages, particularly at about 20 millimeters in diameter, the species *pacificum* has a suture exceedingly like true *Placenticeras* in that the lobes and saddles lie nearly on a line and the parts of the first lateral lobe have become practically independent. At earlier and later stages the primitive first lateral lobe still shows its identity in the arrangement of the parts of the suture and is strongly reminiscent of *Hoplites*. In Plates 1 and 2 of this paper adaptations of Smith's figures are given for comparison with sutures of *Placenticeras meeki*.

Paulcke [7] proposed to place such forms as *Placenticeras pacificum*, which have evident relationship to *Hoplites*, and certain species of *Hoplites* that show a transition toward *Placenticeras* in a group with the name *Hoplitoplacenticeras*. For the forms nearer *Hoplites* he would italicize the first half of the name; for those nearer *Placenticeras*, the second half of the name; for truly intermediate forms he would italicize the entire name. The writer believes it less complicated to use an entirely distinct name where a generic distinction is necessary.

The writer therefore approves and accepts Spath's proposal of the name *Metaplacenticeras* to include the forms now called *Placenticeras pacificum* J. P. Smith, *P. californicum* Anderson, and *P. sanctaemonicae* Waring,[8] from the Cenomanian part of the Chico formation of California, and probably also some of the forms included by Paulcke [9] under the names *Hoplites plasticus-costatus* and *H. plasticus-laevis*, from the Senonian of Patagonia. The essential characters of the genus and its differences from *Placenticeras* are shown in the following tabular comparison based on Smith's description of *P. pacificum* and the writer's study of *P. meeki* and other material from the Montana group and the Chico formation.

Metaplacenticeras Spath.	*Placenticeras* Meek
Genotype *M. pacificum* J. P. Smith. Shell large, discoidal, involute, compressed.	Genotype *P. placenta* De Kay. Shell large, discoidal, involute, compressed.
Whorls stout, rounded to diameter of 4.5 millimeters (2 whorls); higher than wide with channeled venter at diameter of 7 millimeters (3 whorls); very high, compressed, with narrow tricarinate venter to diameter of 100 millimeters; large adults have compressed whorl with venter narrow, flat or slightly concave, bordered by finely nodose keels.	Whorls stout, rounded to diameter of 3 millimeters (1½ whorls); higher than wide with flat venter at diameter of 4 millimeters (1¾ whorls); very high, compressed, with narrow channeled venter bordered by sharp continuous or nodose keels or with narrow flat venter to diameter of perhaps 200 millimeters; large adults of most species have rounded venters. In some species the adult whorls are stout, even subquadrate (*Stantonoceras* Johnson).
Umbilicus relatively wide, one-fifth the diameter of the shell, with shoulder rounded in young and angular with steep inner wall in later stages.	Umbilicus narrow in typical forms, one-seventh the diameter, with rounded shoulder; gentle inner slope in the young and steep in later stages. Stout species have relatively wide umbilicus, much as in *Metaplacenticeras*.
Sculpture of distinct, fairly strong numerous ribs in all stages above a diameter of 2 or 3 millimeters. Ribs striated and sigmoid in form. Umbilical shoulders and ventrolateral keels with numerous tubercles.	Sculpture weak; faint ribs in the very young stages and none or only low obscure coarse ribs in the later stages. Surface with sigmoid striae. Tubercles when present not usually strong nor numerous.
Suture in adult has four prominent lateral lobes and three or four smaller lateral lobes. First prominent lateral smaller and arises as a marginal in the primitive first lateral saddle; next three arise by division of the primitive first lateral lobe, which in the growth of the individual first loses and then regains its identity. Even in the adult it retains to some extent its individuality. The fifth lateral lobe of adult is a direct descendant of the primitive second lobe.	Suture in adult has three prominent lateral lobes and six or seven smaller lateral lobes. First prominent lateral develops from a marginal of the primitive first lateral saddle; next two arise by division of the primitive first lateral lobe, which very early loses its identity. The fourth lateral lobe is the direct descendant of the primitive second lateral lobe.

[6] Hyatt, Alpheus, op. cit., pl. 45, figs. 11–14, 1903.

[7] Paulcke, Wilhelm, Die Cephalopoden der oberen Kreide Sudpatagoniens: Naturf. Gesell. Freiburg Ber., vol. 15, pp. 178–183, 1907.

[8] Waring, C. A., Stratigraphic and faunal relations of the Martinez to the Chico and Tejon of southern California: California Acad. Sci. Proc., vol. 7, p. 70, pl. 9, figs. 20, 21, 1917.

[9] Paulcke, Wilhelm, op. cit., pp. 178–183.

PLATES 1–2

PLATE 1

FIGURES 1–7. *Placenticeras meeki* Boehm, from a locality near the center of sec. 2, T. 32 N., R. 86 W., Natrona County, Wyo. (U. S. Nat. Mus. catalog No. 73133.)

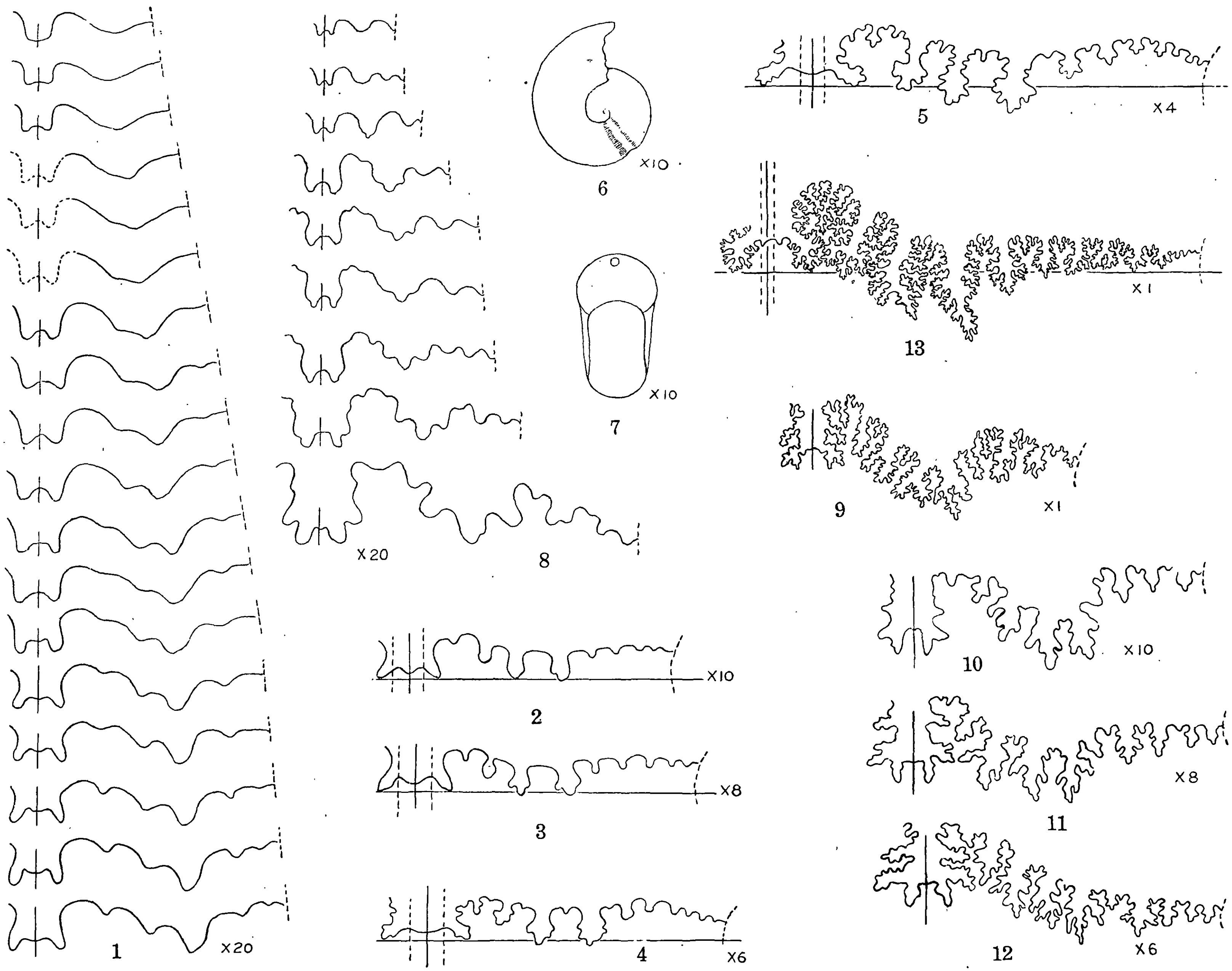
1. Group of 18 consecutive sutures from a diameter of 1.4 millimeters to a diameter of 4.0 millimeters.
2. Suture at diameter of 7 millimeters.
3. Suture at diameter of 10 millimeters.
4. Suture at diameter of 14 millimeters.
5. Suture at diameter of 25 millimeters.

6, 7. Side and front views of the nucleus.

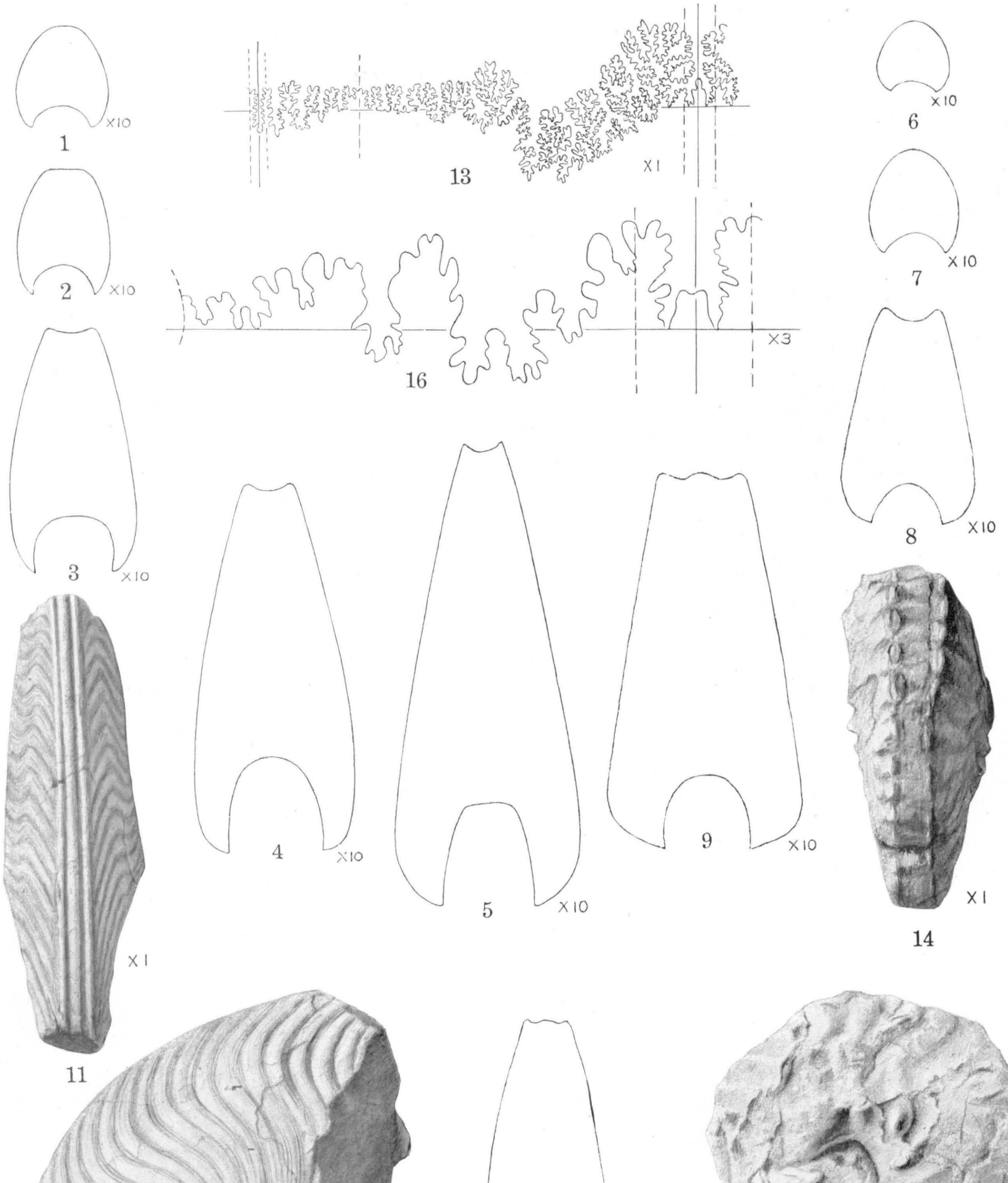
8–12. *Metaplacenticeras pacificum* (Smith). Figures adapted from J. P. Smith, California Acad. Sci. Proc., 3d ser., vol. 1, pls. 27 and 28.

8. Nine sutures at diameters of 0.8, 1.16, 1.32, 1.70, 2.2, 2.4, 2.7, 3.0, and 4.1 millimeters for comparison with Figure 1.
9. Mature suture.
10. Suture at diameter of 8.5 millimeters for comparison with Figures 2 and 3.
11. Suture at diameter of 12.0 millimeters for comparison with Figures 3 and 4.
12. Suture at diameter of 14.1 millimeters for comparison with Figure 4.

13. *Placenticeras meeki* Boehm, mature suture at diameter of 110 millimeters, of a specimen from the Bearpaw shale 2 miles southwest of McLean's ranch, on Sage Creek, Alberta, Canada; for comparison with Figure 9 and with Plate 2, Figures 13 and 16. (U. S. Nat. Mus. catalog No. 73134.)



SPECIES OF PLACENTICERAS AND METAPLACENTICERAS



SPECIES OF PLACENTICERAS AND METAPLACENTICERAS

PLATE 2

FIGURES 1– 5. *Placenticeras meeki* Boehm, from a locality near the center of sec. 2, T. 32 N., R. 86 W., Natrona County, Wyo. (U. S. Nat. Mus. catalog No. 73133.) Five cross sections of the whorl at diameters of 3, 4, 7, 10, and 14 millimeters.

6–10. *Metaplacenticeras pacificum* (Smith). Figures adapted from J. P. Smith, California Acad. Sci. Proc., 3d ser., vol. 1, pl. 28. Five cross sections of the whorl at diameters of 3, 4.5, 7, 12, and 21 millimeters for comparison with Figures 1 to 5.

11–13. *Metaplacenticeras pacificum* (Smith). Side and peripheral views and suture of a specimen from the Chico formation in Silverado Canyon, Orange County, Calif. (U. S. Nat. Mus. catalog No. 73135.)

14–16. *Metaplacenticeras californicum* (Anderson). Side and peripheral views and suture at diameter of 50 millimeters of a specimen from the Chico formation in Bowers Canyon, in the Santa Susana Mountains, about 4 miles southwest of Chatsworth Park, Los Angeles County, Calif. (U. S. Nat. Mus. catalog No. 73136.)

THE MONTANA EARTHQUAKE OF JUNE 27, 1925

By J. T. PARDEE

SUMMARY

The earthquake of June 27, 1925, in Montana caused considerable damage within an area of 600 square miles or more, the center of which is in latitude 46° 5′ N. and longitude 111° 20′ W., a short distance southeast of Lombard. It was a seismic disturbance of the first order of magnitude, but, owing to the hour at which it occurred and to other fortunate circumstances, no lives were lost and no fires broke out. The shock was startling throughout an area extending 75 miles or more in all directions from the epicenter and was sensible to persons within an area of 310,000 square miles. Within the epicentral area brick buildings suffered severely, rocks fell from cliffs, cracks opened in the ground, and the inhabitants experienced the usual symptoms of illness and emotions of alarm. Isoseismals drawn according to the Rossi-Forel scale show a wide indentation at the south due to a rapid decline of intensity in the volcanic area of Snake River Plain and Yellowstone Park.

The main shock was preceded by two light foreshocks and followed by a great many aftershocks, one of which, occurring about three-quarters of an hour later, was almost as severe as the main shock.

The epicenter is in Clarkston Valley, a lowland surrounded by mountains of severely folded Mesozoic and older rocks and floored with Tertiary "lake beds" and Recent alluvium. Physiographic evidence indicates that Clarkston Valley is a structural depression bounded on the east by a fault of post-Miocene age. Presumably the origin of the earthquake was on this fault at a considerable depth below the surface. It is concluded that the region is in a state of moderate seismic activity and is likely in the future to be visited by an occasional severe shock.

INTRODUCTION

On June 27, 1925, practically all of Montana and parts of the neighboring States and Provinces were shaken by an earthquake of marked intensity. The shock, which was immediately preceded by a light foreshock, came at approximately 6.21 p. m., mountain time. Newspaper reports published the following days indicated that the greatest damage occurred in the villages of Three Forks, Logan, and Manhattan and at Deer Park, where a large rock slide blocked the Chicago, Milwaukee & St. Paul Railway. The area thus indicated lies from 20 to 40 miles northwest of Bozeman and about 55 miles east of Butte and an equal distance southeast of Helena. The epicenter as subsequently determined is a short distance southeast of Lombard, at approximately 46° 5′ north latitude and 111° 20′ west longitude. Three Forks contains about 1,200 inhabitants, Manhattan 600, and Logan 300. The remainder of the area of high intensity is very thinly inhabited.

The effects of the earthquake were investigated by the writer within the periods of July 10 to 31 and August 29 to September 5, 1925. Most of the settlements within a radius of 50 miles of the epicenter were visited, and trips were made to a few more distant points. The work consisted mainly in observing the remaining visible effects upon structures and natural objects and obtaining first-hand records from individual observers. In addition the geologic features of the epicentral area were briefly examined. (See pls. 3 and 4.)

For valuable information the writer is indebted to the many persons interviewed, and in particular to W. T. Lathrop, of the United States Weather Bureau at Helena; J. P. Swarts, W. P. Luburg, and H. P. Allen, Northern Pacific Railway operators at Lombard; and A. D. Burkett, chemist of the Three Forks Portland Cement Co. at Trident.

EFFECTS OF THE EARTHQUAKE

DAMAGE TO BUILDINGS

The greatest damage caused by the earthquake was shown by the school buildings at Manhattan, Logan, and Three Forks and a church at Three Forks (pls. 5 and 6), all of which were built of brick. The church is almost a complete wreck. The schoolhouses, though very seriously damaged, were not beyond repair. In the business sections of Three Forks and Manhattan most brick, stone, and cement-block buildings were seriously damaged, but none were completely wrecked. Some brick and cement houses and virtually all frame buildings escaped serious injury. Rather serious damage was done to brick schoolhouses at Willow Creek, Bozeman, Radersburg, and White Sulphur Springs, to the courthouse and jail at White Sulphur Springs (pl. 6, *B*), and to cement walls and cement block buildings at Trident. Damages to five schoolhouses in Gallatin County (two at Manhattan and one each at Three Forks, Logan, and Willow Creek) were estimated by the State architect at approximately $62,000. The additional property loss in the towns mentioned probably is not large. There was also damage at many other places within a radius of 75 miles of the epicenter. This damage consisted mostly of breaks in chimneys, plaster, and plate-glass windows

In addition many persons suffered losses by reason of merchandise and household effects being thrown about and broken. No estimates of the amounts of these losses are available.

From even a casual inspection it is apparent that all well-constructed buildings of whatever type escaped with little damage. Buildings faced or veneered with brick laid up without being tied or bonded to the inner walls suffered the most. The schoolhouses (pls. 5 and 6) are conspicuous examples. In Three Forks several walls made of common brick tied in the usual way with a layer of "headers" every fifth or sixth row were observed to be practically undamaged, though they adjoined veneered or faced walls that had failed. Some walls tied as described were wrecked, but their failure was due to poor mortar, as shown by the fact that the fallen bricks were generally separated from one another. At White Sulphur Springs part of the cornice and veneer on the one-story brick jail was sheared from the inner wall, owing to the lack of ties or bonding (pl. 6, *B*). In the same town the peaks of the walls forming the gable ends of a two-story brick school and the two-story stone courthouse fell. The school had previously been condemned as unsafe, but the courthouse, though old, was apparently a substantial building. The gable peaks probably fell because they lacked the support of adjoining walls. At Radersburg the brick veneer on the one-story schoolhouse was partly sheared off.

DAMAGE TO RAILROADS

At the west portal of tunnel No. 8, near Deer Park, on the Chicago, Milwaukee & St. Paul Railway, the earthquake caused a rock slide, estimated at 40,000 cubic yards, that not only blocked the track but obstructed the canyon of Sixteenmile Creek, causing a lake to form (pl. 7, *B*). Two weeks was required to build a temporary track around the slide, so that the railroad could resume traffic over this part of its line. Clearing the permanent track would, it was estimated, take several months. A report current in newspapers soon after the earthquake that the tunnel at Deer Park had been destroyed was erroneous. It had been clogged by débris at one portal but otherwise was undamaged. Between Deer Park and Lombard rocks fell on the track at several places, without, however, causing serious damage. At Cardinal a water tank of an older type, supported by timbers, was thrown down. At several places near Lombard the Northern Pacific Railway track was broken or obstructed by masses of fallen rock (pl. 8).

DAMAGE BY FIRE

Fortunately, no fires were caused by the earthquake, but an indirect result of it was a fire the night of July 20 which destroyed the main business block in Toston. This fire caught from a chimney that had been cracked by the earthquake and was not yet repaired. Efforts to put out the fire were hindered by a lack of water, due also to the earthquake, which had cut off the public supply formerly derived from gravel beneath the dry channel of Sixmile Creek.

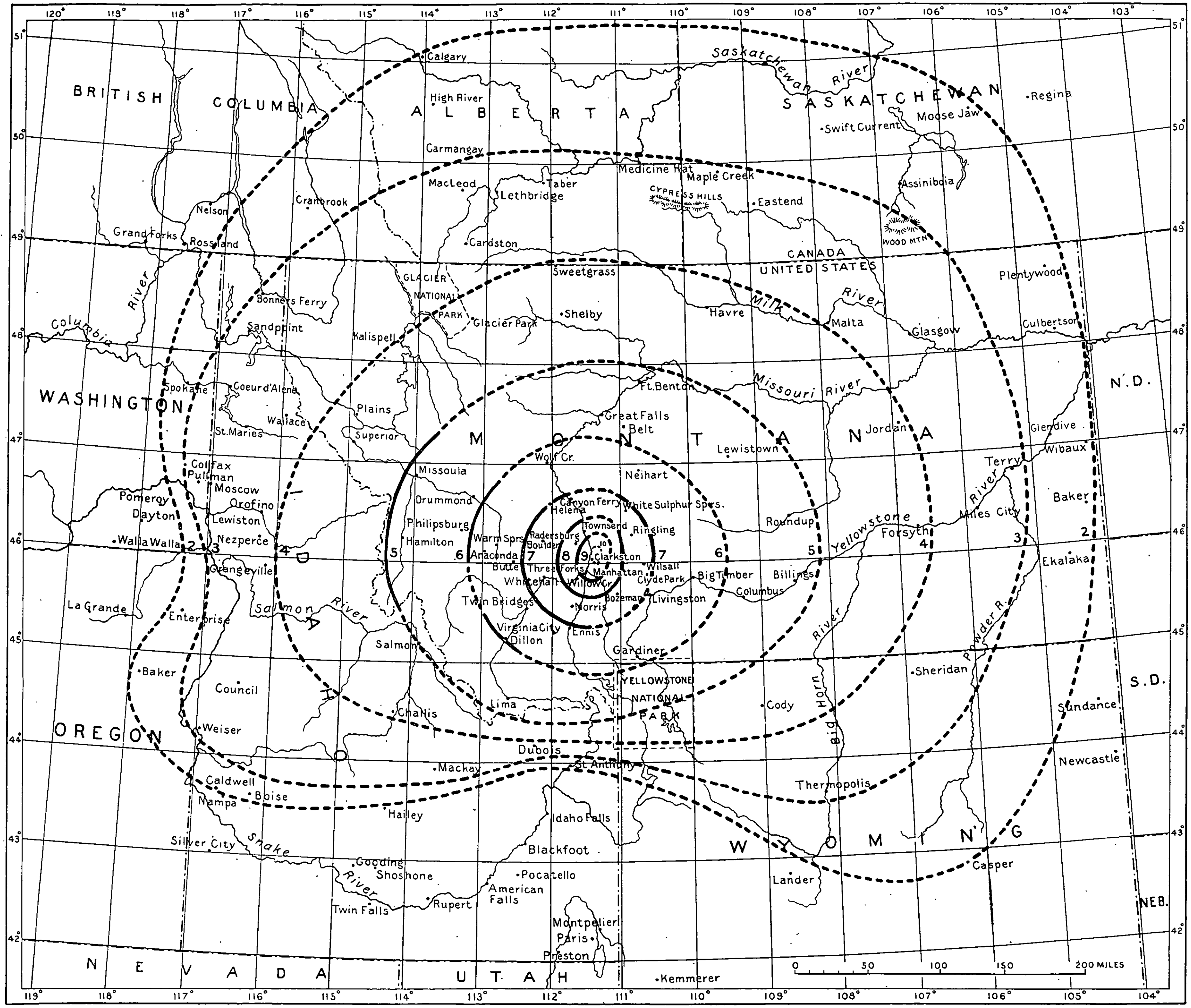
INJURY TO PERSONS

Though many persons experienced narrow escapes in the Montana earthquake, none lost their lives, and only two were reported to have been injured. This fortunate lack of casualties is no doubt due to the fact that the shock came at a time when schools, churches, and other places of public assembly were vacant. The people were mostly on the streets or in their homes and away from the larger buildings that collapsed. At Three Forks a woman had a leg broken as a result of falling or being thrown down by the shock, and near Ennis a man received slight injuries when the vibrations sheared the automobile in which he was riding off of the road. A west-bound Chicago, Milwaukee & St. Paul Railway passenger train in two sections and a Northern Pacific Railway local passenger train were in the epicentral area near Lombard when the shock came. The Chicago, Milwaukee & St. Paul train sections had only a few minutes before passed the place where the Deer Park slide buried the track. They came to a stop while huge rocks were falling on the tracks in front of them and behind them, and their escape without a scratch seems little short of miraculous.

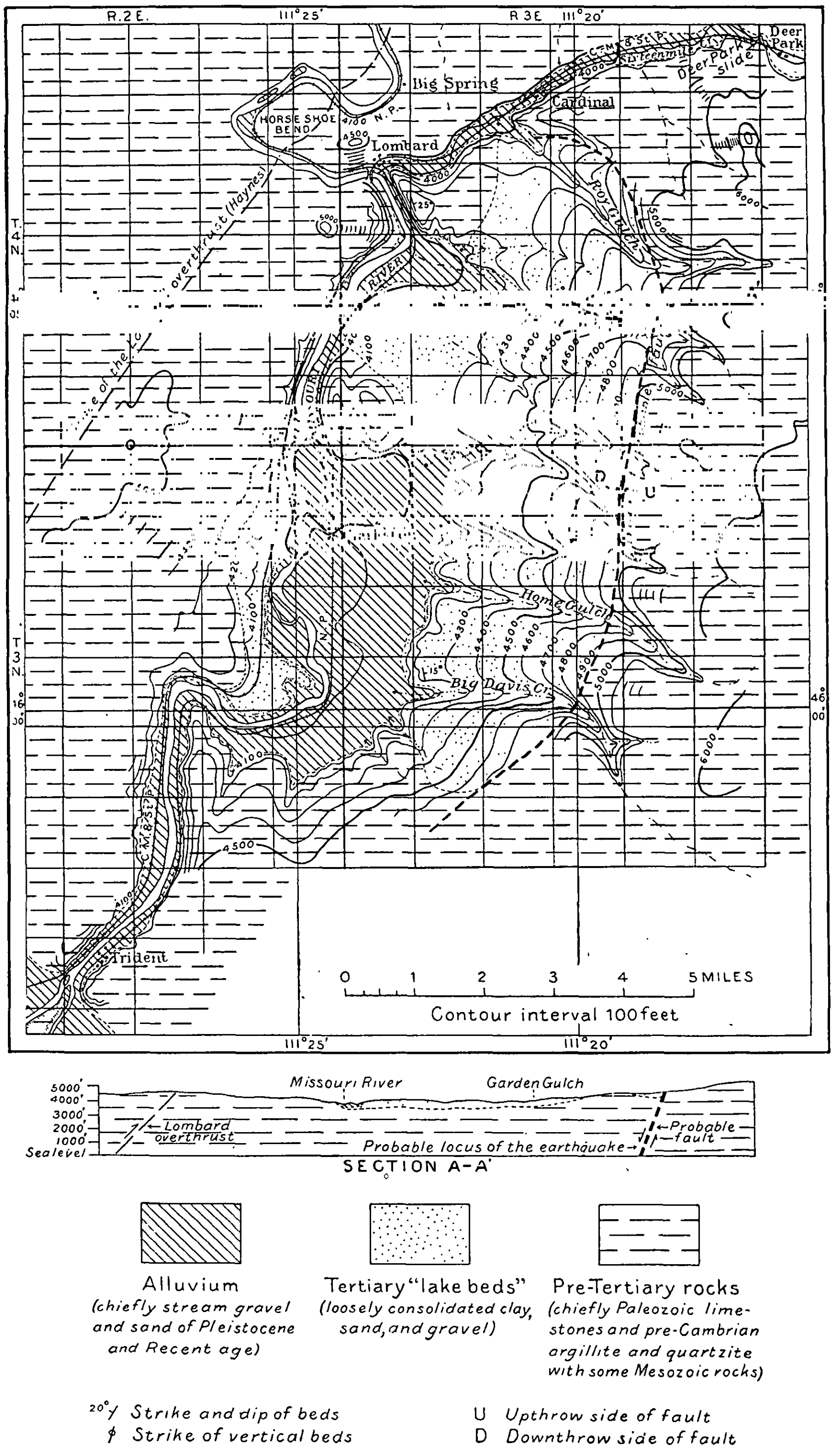
EMOTIONS, SENSATIONS, ETC.

The earthquake was violent enough to alarm the inhabitants generally throughout an area having a radius of as much as 75 miles from the epicenter. In Three Forks and other places near the epicenter many persons became wildly excited or hysterical, and the alarm caused by the main shock was renewed and increased by several of the closely following aftershocks. Because of earth motion during the heaviest parts of the main shock and of the first aftershock many persons were unable to walk or go toward a door or in any other certain direction. Near Three Forks a man who had raised his foot to step over a ditch was unable to change this pose for a few seconds; then he fell into the ditch. Persons sitting were unable to rise out of their chairs. A man who was in one of the damaged schoolhouses at Manhattan probably owes his life to the fact that he was unable to get to the door for a few seconds, during which several heavy masses of brick fell just outside. Many persons were partly or completely thrown down and in falling caught at the nearest object for support. A lady thus thrown in the street at Three Forks found herself clasping the knees of a strange man.

As soon as persons were able to regain their feet or make progress despite the earth movements they lost



ISOSEISMAL LINES FOR MONTANA EARTHQUAKE OF JUNE 27, 1925



GEOLOGY OF THE EPICENTRAL AREA FOR MONTANA EARTHQUAKE OF JUNE 27, 1925 no time in getting out of doors. In their excitement some persons picked up articles of no value. At Butte a woman is said to have laid down her baby and picked up the cat. Within a large area nearly everyone experienced more or less dizziness or nausea, and many felt a nervousness difficult to overcome for days or weeks afterward.

Most persons who had not already eaten failed to get their suppers that night. Near the epicenter many tables with suppers already served were thrown to the floor in a general mixup with other household articles. At Three Forks and places similarly situated dishes were commonly upset, and in general the people became too excited or ill to think of eating. Many of the inhabitants of Three Forks, Manhattan, and other places and even a few as far away as Butte and Anaconda remained out of doors part or all of the night after the earthquake. At Three Forks and other places that suffered conspicuous damage to buildings the people wisely did their cooking out of doors for several days or until their chimneys could be repaired. Fortunately, because it was summer, this caused the least amount of inconvenience, and for the same reason the houses did not need to be warmed. There is record of only one fire resulting from the use of a damaged chimney (p. 8).

Fright or terror was exhibited also by domestic animals within the area of startling shock, but few details were obtained on this phase of the subject.

EFFECT UPON MINES

Contrary to a rather widespread apprehension, the workings of mines were not damaged by the earthquake, and in fact the shock was not generally noticed by the miners who were underground at the time. At Barker a group of miners who were at work in a stope at a depth of 250 feet did not feel the shock, though it was generally noticed in that neighborhood by persons at the surface. So far as learned the thousands of miners at Butte who were underground at the time were generally unaware that an earthquake had occurred. In view of the fact that mine workings are generally constructed so as to withstand the jars from blasting, it is not surprising that they would resist damage by the less violent vibrations of this earthquake. Owing to the common occurrence of the jars caused by blasting, miners at work would not be likely to notice especially the somewhat similar vibrations of seismic origin. Furthermore, as these vibrations are less destructive in areas of solid rock than in loose materials, they would be less noticeable underground than at the surface.

ROCK SLIDES

Rocks and rock masses were shaken down rather generally from the steep slopes and cliffs existing within a radius of 12 or 15 miles of the epicenter, and a few rock falls occurred as far away as 40 miles.

Deer Park slide.—The largest mass dislodged by the earthquake was that which blocked the valley of Sixteenmile Creek at the west portal of tunnel No. 8, near Deer Park (pl. 7, *A*). The size of this slide does not mean, however, that the shaking was more severe in that locality than elsewhere, but that at that point an unusually large mass was already sufficiently loosened by erosion to be easily shaken down. Tunnel No. 8 goes through a narrow limestone spur that projects a short distance from the south wall of the canyon and causes Sixteenmile Creek to make a north bend (pl. 4). At the point of the spur the canyon is narrow, and its floor is practically occupied by the stream, which is 10 to 12 yards wide. Above and below the spur the canyon widens a few hundred feet. The east side of the spur, which faces upstream, is a sheer wall of limestone (pl. 7, *B*), which before the slide was 100 to 300 feet high. The north side of the canyon opposite the spur is a similar wall, and the west or downstream side of the spur is only a little less precipitous. Surmounting the walls on both sides of the canyon are steep slopes that rise 1,000 feet higher. The gorgelike constriction of the valley at this place is due to a belt of resistant Paleozoic limestone that trends northward across the course of the stream. The bend in the gorge is probably an incised meander. The limestone dips about 30° W. and therefore inclines downstream and at right angles to the axis of the spur. A fault or slip plane that coincides nearly with the bedding (pl. 9) touches the top of tunnel No. 8 at or near its west portal. Its trace appears about 60 feet above the tunnel at the east portal, in the vertical east wall of the spur (pl. 7, *B*). This trace is visible farther south and also across the stream on the north side of the canyon (pl. 10, *A*), where it shows the maximum dip. Above and below this fracture are other similar slip planes. All of them probably were caused by the readjustments between the beds necessitated by the folding, and none are to be regarded as major structural features.

The mass of the spur above the fault plane described fell during the earthquake. Prior to that event its supports had been cut away on all sides except the south. The shaking, therefore, easily broke it loose along joints and minor fractures and started it sliding down the inclined floor on which it lay. Scratches made on this plane by the sliding mass go across small grooves and ridges made during previous fault movements.

Slides near Lombard.—For a mile or more north and south of Lombard, Missouri River is bordered on the east side by limestone cliffs and talus slopes several hundred feet high (pl. 10, *B*), at the foot of which the Northern Pacific Railway is built. On the west side of the river are lower cliffs beneath which the Chicago, Milwaukee & St. Paul Railway passes for a short distance. Fortunately, the bedding planes in the cliffs east of the river are nearly horizontal. If their dip was toward the river slides probably exceeding that near Deer Park would have occurred. Joint planes were opened in these rocks, however (pl. 11, *A*), and considerable material was shaken down (pl. 8, *B*). Solid masses weighing as much as 100 tons were detached from the cliffs and rolling down smashed the track (pl. 8, *A*). One of these masses estimated to weigh 30 tons is illustrated on Plate 11, *B*. Along Sixteenmile Creek below the Deer Park slide and along Missouri River west of Lombard the Chicago, Milwaukee & St. Paul track was similarly obstructed in many places. In all tributary canyons or other places near by where steep or cliff-like slopes occur much material was dislodged and added to the talus accumulations already existing. Observers along Sixteenmile Creek reported that for some time after the rocks began to fall the air was filled with a dense and choking dust. At Lombard the cliffs were hidden for several minutes by a cloud of dust, below which the rock débris could be seen rolling and sliding down to the river.

Rock falls in outlying areas.—Beyond the epicentral area rock falls of comparatively small extent occurred along the bluffs adjacent to Madison River south of Three Forks, along Jefferson River above Willow Creek, near Accola, and near Canyon Ferry. Most of these were masses that were well on the way to being let down by the ordinary processes of erosion. Dust arising from some rock falls near Willow Creek appeared from a distance like smoke and led to the report that the town was on fire.

GROUND CRACKS

Newly formed ground cracks were observed in many places within a radius of 15 or 20 miles of the epicenter and also at one place, Canyon Ferry, about 40 miles distant. Apparently all were due to the shaking, and none represented a surface slip along the line of a deep-seated fault. Those described in the following paragraphs were observed in or near the epicentral area.

Roy Gulch.—Cracks on both sides of Roy Gulch, a short distance southeast of Cardinal, extend for a quarter of a mile or more in a southeasterly direction parallel to the gulch and bound an area of alluvium that in places has settled 2 feet or more. At the top of the slope southwest of the gulch is a series of more or less continuous cracks extending also in a southeasterly direction for a mile or more. These cracks are branching, and at one place they occupy a zone several feet wide in which the ground is completely shattered and broken into clods that have been shuffled about and overturned (pl. 12, *A*). The cracks appear to extend through the soil and into the underlying Tertiary "lake beds," which here consist of moderately hardened layers of clay and sand.

Garden Gulch.—In the bottom of Garden Gulch, about 3 miles south of Cardinal, several cracks were observed in alluvium, causing certain areas to settle and thus obstruct the flow of water through ditches. At another place three cracks having a direction a little west of south cut across a ridge of Tertiary "lake beds." These cracks are each 100 yards or more long and from 1 to 3 or 4 inches wide. The ground on the west side of each had settled slightly.

North of Cardinal.—Near the ranches of Jonas Stockburger and Dave Johnson, respectively about 2 miles northeast and 3 miles north of Cardinal, many ground cracks were observed that range from 50 to 200 or 300 feet in length and from 1 to 3 inches in width. These occur in a hilly region composed chiefly of Paleozoic limestones bearing a rather thin soil or surface mantle. The cracks appear in the soil and generally follow along the foot of a hill just below the outcrops of bare rock. Whether or not they penetrate the rock beneath the soil is not shown. As a rule the area on the lower side of each crack has settled a little.

Near Three Forks.—On the highway northeast of Three Forks a crack several rods long and several inches wide opened in the embankment forming the approach to the bridge over Jefferson River. The crack had been filled up and was not visible when the writer visited the scene, but evidence of it is given by a photograph (pl. 12, *B*). A report published in the papers soon after the earthquake stating that a fissure had opened extending continuously from Three Forks to Manhattan was apparently without foundation.

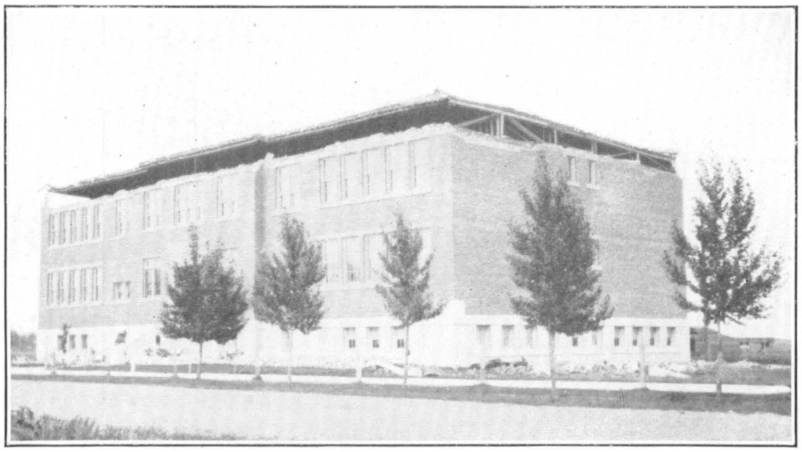
Greyson Creek.—At John Denzer's place, about 15 miles north of Cardinal, on alluvial land bordering Greyson Creek, a crack opened more than 100 yards long and 6 inches in maximum width. It is parallel to the creek, and the bank on that side has settled a little.

Canyon Ferry.—In the field of William Ames, near Canyon Ferry, cracks 2 or 3 inches in maximum width (pl. 13, *A*) partly surround an area of an acre or less that has settled slightly. This block lies in an area of alluvium in the valley near the edge of the bench lands. It includes a shallow swale that is not crossed by a stream, the swale apparently being the result of settling at some former time.

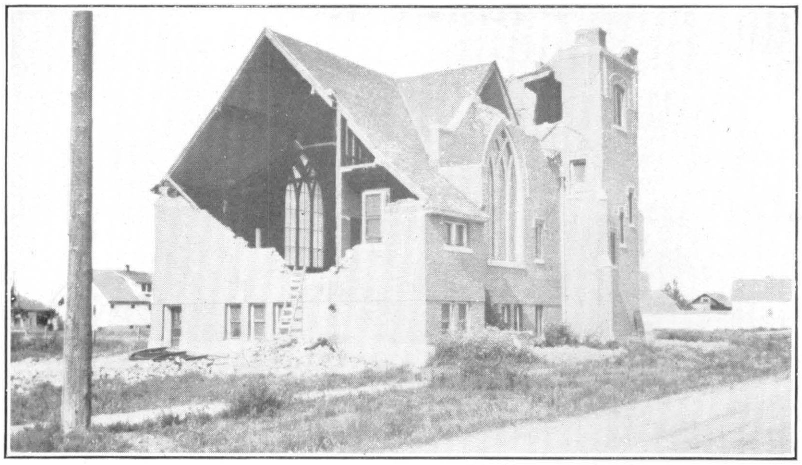
CHANGES IN SPRINGS AND WELLS

Many springs within a radius of 50 miles from the epicenter were increased or diminished by the earthquake. Some were made turbid for a short time. Several wells went dry, and others became muddy. The ground-water flow beneath the dry bed of Sixmile Creek, upon which the town of Toston depended mainly for its public water supply,[1] failed shortly after

[1] U. S. Geol. Survey Water-Supply Paper 539, p. 52, 1925.

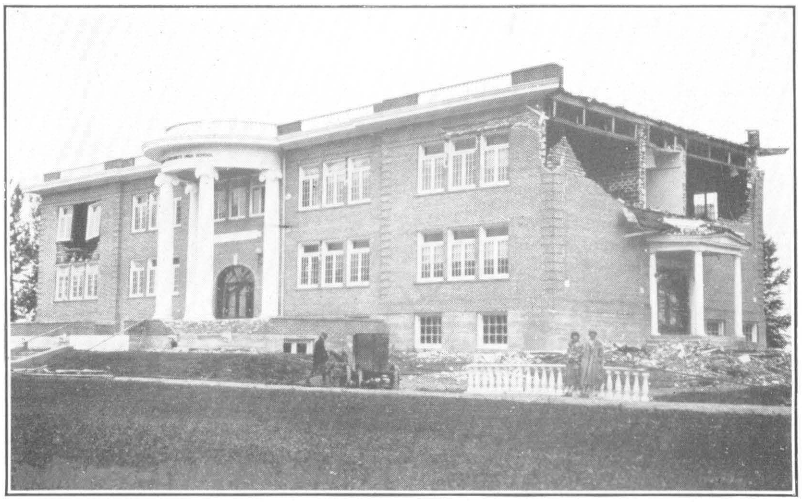


A. DAMAGED SCHOOLHOUSE AT THREE FORKS, MONT.



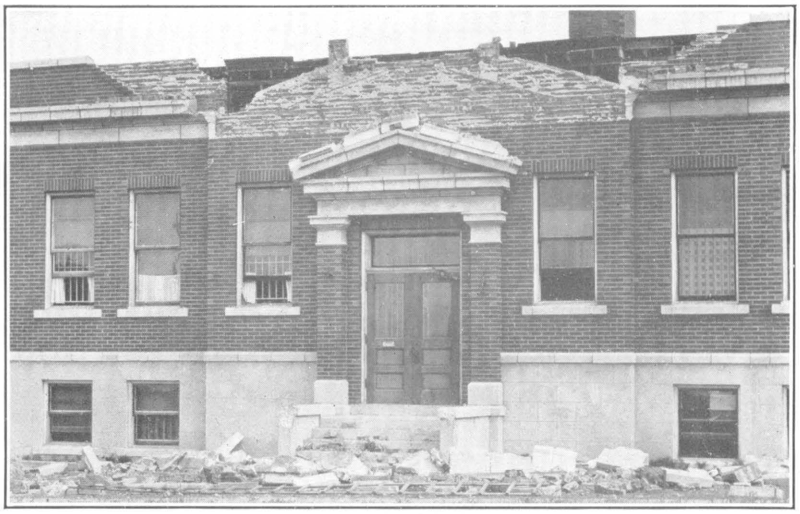
B. WRECK OF CHURCH AT THREE FORKS, MONT.

Note separation of the fallen bricks from one another due to failure of mortar



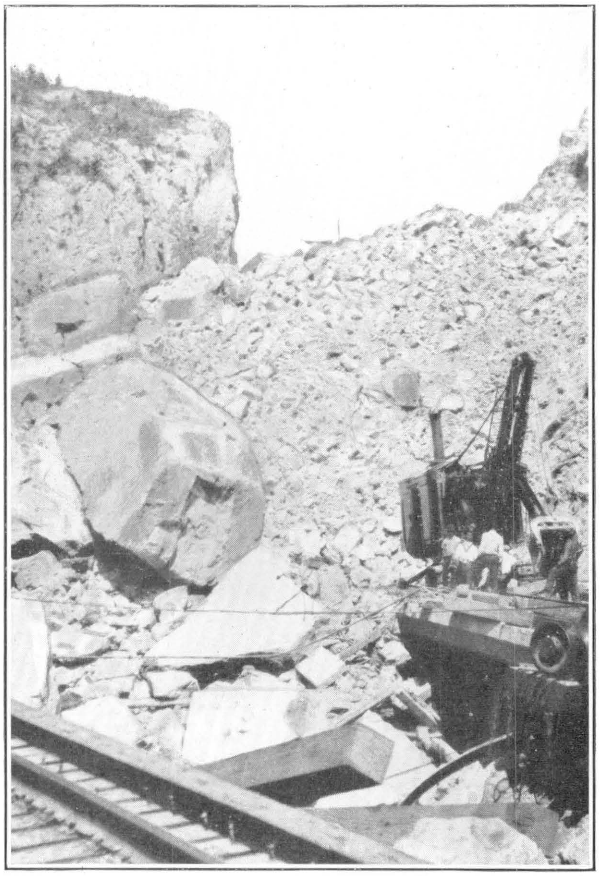
A. DAMAGED SCHOOLHOUSE AT MANHATTAN, MONT.

Note separation of partition walls from outside wall due to lack of ties



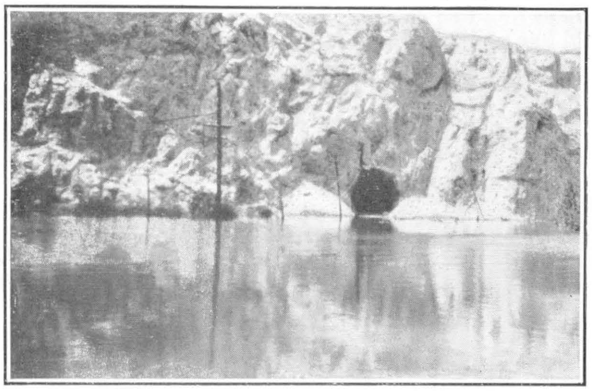
B. DAMAGED JAIL AT WHITE SULPHUR SPRINGS, MONT.

Note shearing of brick veneer from back wall



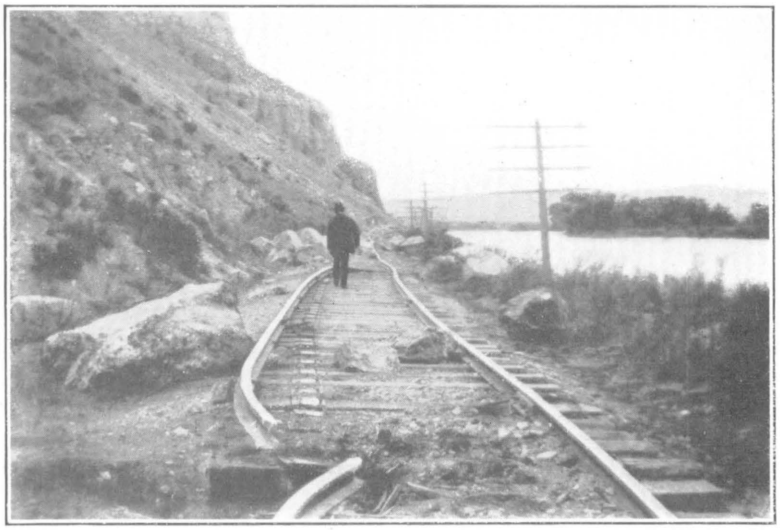
A. ROCK SLIDE NEAR DEER PARK, MONT.

Temporary track in left foreground



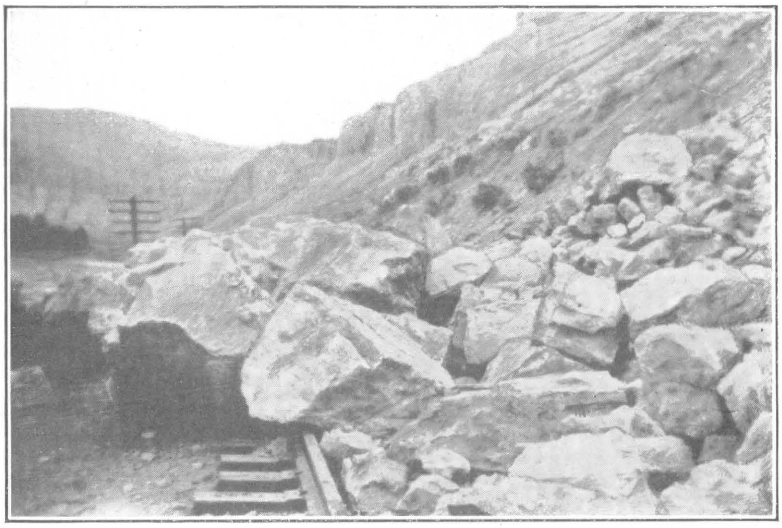
B. LAKE AT TUNNEL NO. 8, NEAR DEER PARK, MONT.

No rock falls occurred within the tunnel. Photograph by H. P. Allen



A. BROKEN RAILROAD TRACK NEAR LOMBARD, MONT.

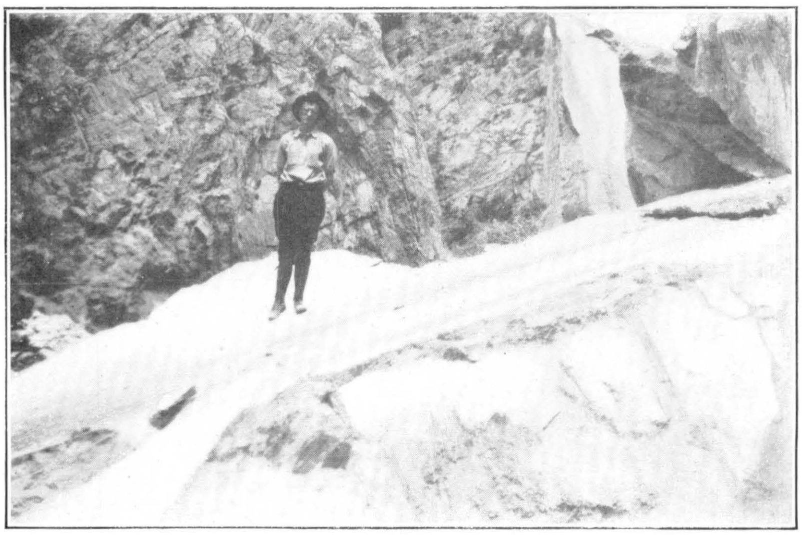
Note rebound of the broken rail. Photograph by J. P. Swarts



B. ROCKS ON RAILROAD TRACK NEAR LOMBARD, MONT.

Photograph by J. P. Swarts

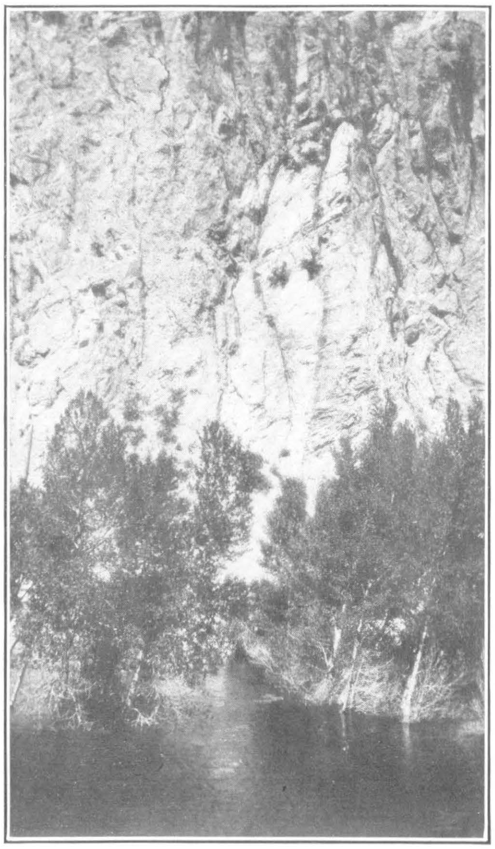
A



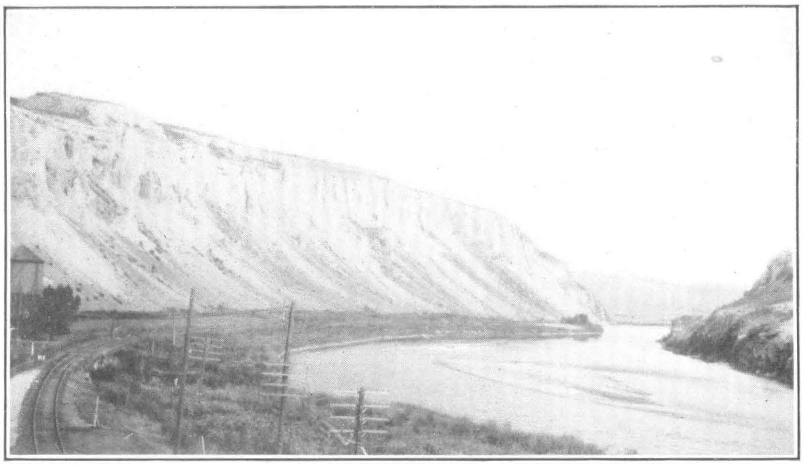
B

FAULT PLANE OF THE SLIDE NEAR DEER PARK, MONT.

Photographs by H. P. Allen

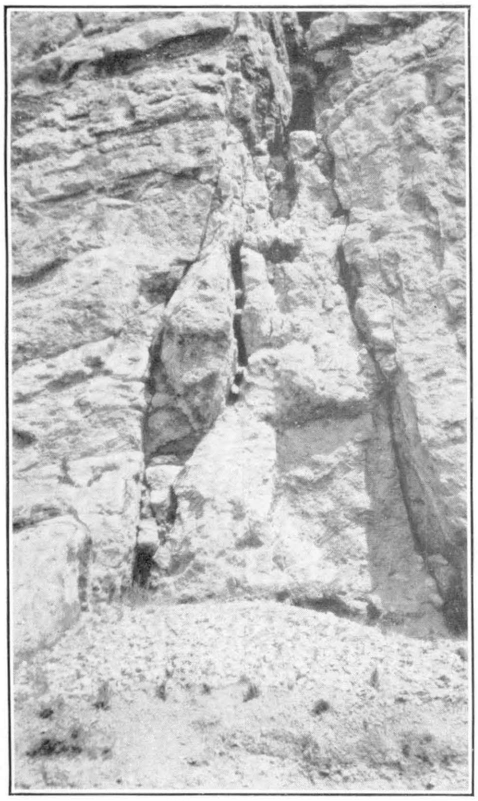


A. NORTH WALL OF GORGE BELOW DEER PARK, MONT.

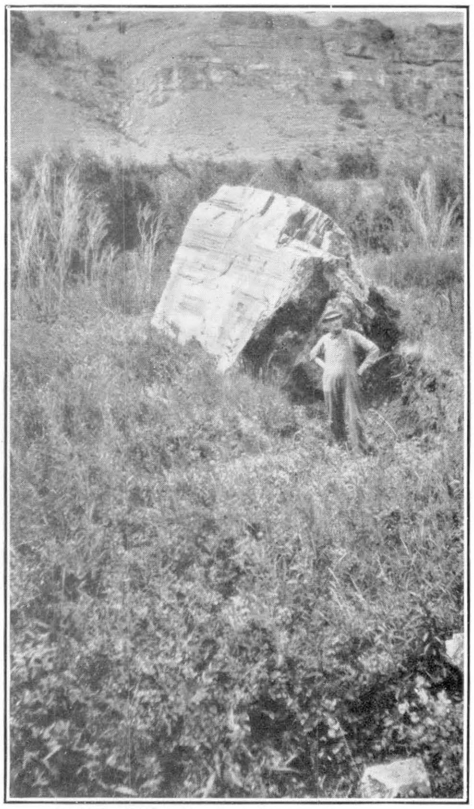


B. LIMESTONE CLIFFS AND TALUS SLOPE EAST OF MISSOURI RIVER AT LOMBARD, MONT.

Lighter-colored streaks on the talus slope represent débris shaken down by the earthquake

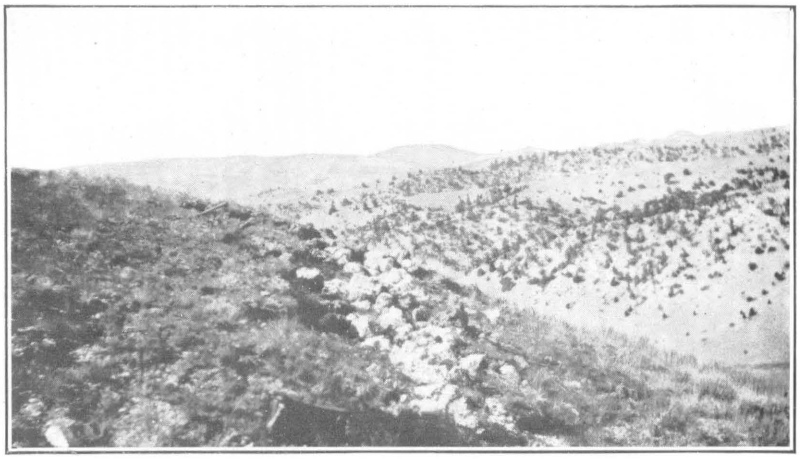


A. JOINTS IN LIMESTONE OPENED BY THE MONTANA EARTHQUAKE



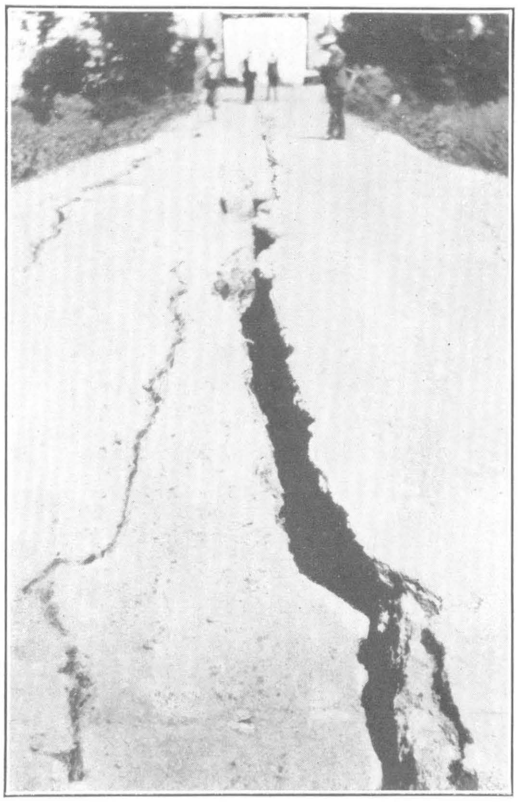
B. BOTTOM LAND ALONG MISSOURI RIVER, MONT.

Boulder dislodged from a cliff by the earthquake and partly buried by the force of its fall

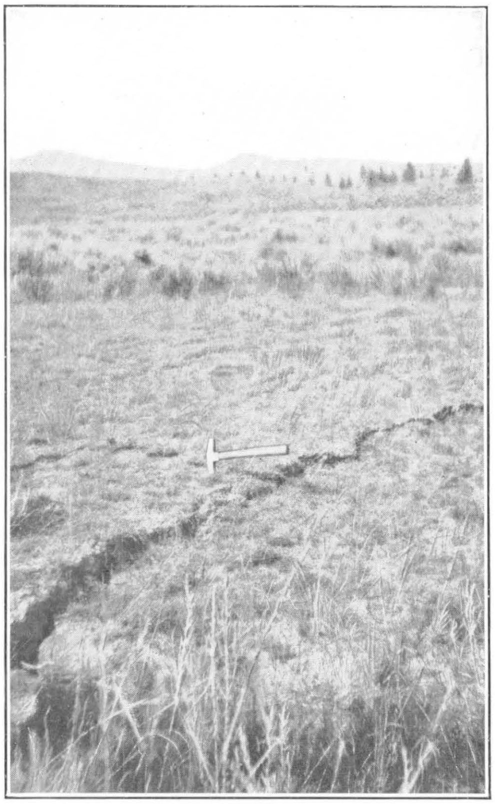


A. SHATTERED GROUND AND OVERTURNED CLODS, ROY GULCH, MONT.

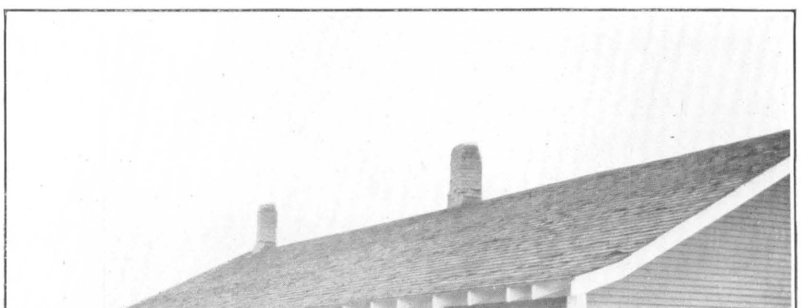
The upturned clods show white because of a deposit of lime "caliche" just beneath the soil



B. CRACK IN ROAD EMBANKMENT NORTH OF THREE FORKS, MONT.



A. GROUND CRACK NEAR CANYON FERRY, MONT.



B. TWISTED CHIMNEYS AT LOGAN, MONT.

the earthquake. Presumably the water was diverted to some other underground channel. Big Spring,[2] above Toston, was said to have been muddy for two days, and the flow of Mockel Spring,[3] south of Radersburg, was considerably increased. Increased flows of hot water are reported by the proprietors of White Sulphur Springs and Alhambra Springs, at Clancy. In the valley of Jefferson River, near Willow Creek, several new springs are said to have broken out, though existing springs went dry. According to press reports, a spring having a flow estimated on July 20 at 100 gallons a minute broke out in a field near Lewistown shortly after the earthquake.

RENEWED FLOW OF OIL AND GAS

An oil well near Cody, Wyo., that had been unproductive for several years "blew" considerable gas and oil for a few days after the earthquake. This well, which probably is the one described in published reports [4] as Shoshone Oil Co.'s well No. 1, is situated north of Shoshone River, 3 miles east of Cody. It was bored in 1909–1912 to a depth of 1,720 feet and found gas and small amounts of oil in several different layers. Its total production, however, probably did not exceed 200 barrels. The well is about 300 feet north of the Cody branch of the Chicago, Burlington & Quincy Railroad and 300 feet east of Cottonwood Creek. W. O. Taylor, of Cody, who witnessed the recurrence of activity, reports that the well started flowing about noon of the day after the earthquake. By the middle of the afternoon the flow had reached such proportions that the fire hazard appeared too great for trains to pass. Throughout the afternoon the well threw a column of mixed oil and water accompanied by gas from 30 to 40 feet in the air. The flow of gas was estimated at about 5,000,000 cubic feet a day, and the oil and water together at 1,500 barrels a day, the proportion of oil ranging from 5 to nearly 100 per cent. At 7 o'clock the next morning (June 29) the well was still spouting 10 or 15 feet in the air and making considerable oil. At 9 o'clock the flow had ceased. As a result of the well's activity the ground had become oil soaked for 100 feet around it.

Since the spurt described the well has remained quiet, and at the time of Mr. Taylor's report (Dec. 19, 1925) oil stood in the casing about 60 feet below the top.

Edwin Binney, jr., of New Haven, Conn., who visited the scene about three weeks after the earthquake, observed evidences of the recent activity of the well as described. Mr. Binney saw the same well in 1924. At that time it was discharging a small amount of gas, and oil was standing in it to the depth of at least 100 feet. The writer is indebted to Mr. Binney for calling his attention to the behavior of this well and suggesting its possible relation to the earthquake.

The well is within the zone in which the earthquake intensity ranged from 4 to 5 on the Rossi-Forel scale. The Byron, Garland, and Elk Basin oil fields in Wyoming, and the Cat Creek and Kevin-Sunburst oil fields, in Montana are also in the same zone; the Salt Creek and other fields in Wyoming are in zones of less intensity. It is not known whether any wells in these fields were affected by the earthquake.

SAND SPOUTS

At Clarkston, in the alluvial bottom lands along Missouri River, a crack opened and sand and water spouted up for several hours. Afterward the crack closed, and at the time of the writer's visit, two months later, nothing could be seen but the deposit of sand spread over a square rod or two. Similar occurrences were reported near Townsend and in the horseshoe basin west of Menard, where water and mud are said to have spouted up like a geyser.

INTENSITY OF THE EARTHQUAKE

The intensities of the earthquake at different places, as shown by the following table, were estimated by the writer from the visible effects upon buildings and natural objects; reports obtained by letter or interview from persons who experienced the shocks, reports made by observers of the United States Weather Bureau, and reports published in the newspapers. Altogether 110 reports were obtained by interviews with persons who were within a radius of 40 or 50 miles of the epicenter. Sixty-five replies were received to letters addressed to postmasters or others in the outlying parts of the disturbed area, and a score or more of reports from scattered points were obtained from Weather Bureau observers and selected from the newspapers.

[2] Idem, p. 46.
[3] Idem, p. 47.
[4] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, pp. 110-111, 1914. Hewett, D. F., and Lupton, C. T., Anticlines in the southern part of the Big Horn Basin, Wyo.: U. S. Geol. Survey Bull. 656, pp. 187-188, 1917.

Intensity and effects of Montana earthquake of June 27, 1925

[Principal shock at 6.21 p. m.]

Place [a]	Latitude N.		Longitude W.		Intensity [b]	Effects, etc.
	°	′	°	′		
Cardinal	46	7	111	22	9+	Extensive rock falls from cliffs. Heavy stove moved east.
Stockburger's, 2½ miles northeast of Cardinal.	46	8	111	20	9+	Furniture in small house thrown violently about. Cracks in ground. Log buildings distorted and made to lean eastward.
Deer Park	46	8	111	19	9+	Extensive rock falls and slides. Heavy stove moved northwest. Other furniture in small house thrown about.
Garden Gulch, 4 miles southeast of Lombard.	46	6	111	20	9+	Loose clods in plowed field "danced and shuffled about." Stove in cabin thrown over eastward. Log cabin sprung out of shape.
Dave Johnson's, 3 miles north of Cardinal.	46	9	111	21	9+	Ground cracks. All loose objects in small frame house thrown about violently.
Lombard	46	8	111	24	9+	Extensive rock falls. Telephone poles leaned strongly to the northwest, then righted. Heavy steel safe in Northern Pacific Railway depot moved to the southeast. Strong surge on Missouri River. Swells formed on railway track.
Perugin's, 9 miles southeast of Townsend.	46	15	111	22	9	Doors of stove jerked off.
Clarkston	46	2	111	24	9+	Ground cracks and sand spout. Visible ground waves.
Jacobs's, 10 miles southeast of Townsend.	46	15	111	22	9	Small frame house distorted. Furniture thrown about.
Denzer's, 8 miles southeast of Townsend.	46	17	111	23	9+	Doors jerked off of hinges. Furniture, etc., thrown about and wrecked. Ground cracks.
Roy Stillman's, 7 miles southwest of Maudlow.	46	4	111	17	9	All loose articles in small house thrown about.
Trident	45	57	111	29	9	All chimneys broken or thrown down. Cement walls and foundations seriously damaged.
Three Forks	45	58	111	33	9	Brick and stone buildings seriously damaged; some partly wrecked.
Manhattan	45	42	111	20	9	Several brick and stone buildings seriously damaged; some partly wrecked.
Logan	45	53	111	26	9	Brick schoolhouse partly wrecked. Chimneys generally overthrown.
Toston	46	10	111	26	9	Many chimneys overthrown. Piano moved eastward. Loose articles on shelves fell eastward.
Mockel's, 7 miles south-southeast of Radersburg.	46	8	111	36	8+	Chimneys overthrown.
Valley of Madison River, 8 miles south of Three Forks.	45	46	111	32	8	Rock falls. Chimneys overthrown. Cracks opened in cliffs. Water thrown out of troughs.
Gallatin Valley, 3 miles south of Manhattan.	45	50	111	20	8+	Chimneys overthrown.
Maudlow	46	8	111	10	8	Some chimneys overthrown. Loose articles fell from shelves.
Accola	45	54	111	13	8+	Rock falls.
Menard	45	58	111	12	8+	Chimneys overthrown.
Radersburg	46	13	111	39	8+	Chimneys overthrown. Some brick and stone buildings seriously damaged.
Walbert's, 9 miles north-northwest of Three Forks.	46	2	111	38	8+	Visible ground waves. Water thrown out of trough.
Doherty's, 6 miles east-southeast of Townsend.	46	18	111	25	8+	Heavy tractor thrown south off the timbers on which it had been blocked up. Chimneys overthrown.
Thompson's, 6 miles east of Townsend.	46	19	111	25	8+	Doors on one-story frame house swung violently. Loose articles fell.
Townsend	46	20	111	32	8+	Loose articles thrown from shelves. Doors and lights swung violently. Some chimneys overthrown.
Willow Creek	45	40	111	39	8+	Brick schoolhouse seriously damaged. Some chimneys overthrown. Plate-glass windows broken. Visible earth waves. Goods spilled from shelves on north and south sides of room. Few articles on west side down.
Steingruber's, 4 miles north of Willow Creek.	45	53	111	39	8	Loose articles thrown about. Rock falls.
Belgrade	45	2	111	11	8	Cornice on brick schoolhouse fell. Some chimneys overthrown. Brick and stone walls cracked.
Carroll's, 9 miles southeast of Maudlow.	46	2	111	6	8	Loose articles thrown from shelves. Chimneys broken.
Helena	46	36	112	0	7	Slight damage to some buildings and a few chimneys wrecked. Loose articles fell from shelves in several stores.
Whitehall	45	48	112	6	7	Top of a two-story brick wall fell off on west side. Chimneys damaged. Some loose articles fell from shelves. Automobiles facing east and west in a garage rolled forward and back in unison.
Jefferson Island	45	47	111	57	7	Buildings and other objects swayed alarmingly.

[a] Localities in Montana except as indicated otherwise.

[b] The figures indicating intensity are those of the Rossi-Forel scale, which as published in the Bulletin of the Seismological Society of America (vol. 11, p. 218) is as follows:

1. Microseismic shock; recorded by a single seismograph or by seismographs of the same model but not by several seismographs of different kinds; the shock felt by as experienced observer.
2. Extremely feeble shock; recorded by several seismographs of different kinds; felt by a small number of persons at rest.
3. Very feeble shock; felt by several persons at rest; strong enough for the direction or duration to be appreciable.
4. Feeble shock; felt by persons in motion; disturbances of movable objects, doors, windows; creaking of ceilings.
5. Shock of moderate intensity; felt generally by everyone; disturbance of furniture, beds, etc., ringing of swinging bells.
6. Fairly strong shock; general awakening of those asleep; general ringing of house bells; oscillation of chandeliers; stopping of pendulum clocks; visible agitation of trees and shrubs; some startled persons leave their dwellings.
7. Strong shock; overthrow of movable objects; fall of plaster; ringing of church bells; general panic, without damage to buildings.
8. Very strong shock; fall of chimneys; cracks in walls of buildings.
9. Extremely strong shock; partial or total destruction of some buildings.
10. Shock of extreme intensity; great disaster buildings ruined; disturbance of the strata; fissures in the ground; rock falls from mountains.

Intensity and effects of Montana earthquake of June 27, 1925—Continued

[Principal shock at 6.21 p. m.]

Place	Latitude N.		Longitude W.		Intensity	Effects, etc.
	°	′	°	′		
Bozeman	45	41	111	3	7	A few chimneys overthrown. A few brick buildings seriously damaged. Chandeliers swung violently. Heavy steel safe moved a few inches south.
White Sulphur Springs	46	33	110	54	7	A few brick or stone buildings seriously damaged. Several chimneys overthrown. Water in a trough splashed out on north and south sides.
Doggett's, 18 miles northwest of White Sulphur Springs.	46	43	111	12	6+	Chandeliers swung violently.
Fort Logan	46	42	111	11	7	Building swayed alarmingly.
House's, 10 miles northeast of Bozeman.	45	50	110	53	6+	Buildings swayed. Some chimneys cracked; one fell.
Clyde Park	45	53	110	37	7	Plaster cracked. Some chimneys overthrown.
Wilsall	46	0	110	39	6+	Some loose objects thrown from shelves.
Ringling	46	16	110	49	7	Cracks in plaster and chimneys.
Canyon Ferry	46	39	111	42	7+	Some chimneys overthrown. Surges on Lake Sewell. Ground cracks. Earth banks fell.
Clancy	46	28	111	58	7	Several chimneys thrown down. Flow of hot springs increased.
Norris	45	34	111	42	7+	Chimneys damaged; some overthrown. School bell rung.
Harrison	45	42	111	48	7+	Cement walls cracked. Chimneys damaged and plaster cracked. Visible earth waves.
Livingston	45	40	110	34	6+	Some chimneys cracked. Loose objects fell.
Eldridge	45	12	111	14	6	Log house shaken strongly. Loose objects moved or rattled.
Ennis	45	21	111	44	6	Hanging lamps swung. A few loose bricks fell from top of wall.
Virginia City	45	18	111	56	6+	Old stone walls and chimneys cracked. A few chimneys down. Plaster cracked. A few bricks sheared from the cornices of some buildings.
Twin Bridges	45	33	112	20	6+	Several chimneys damaged and a few overthrown.
Butte	48	0	112	33	6+	Some old brick walls and chimneys cracked or fallen. Chandeliers swung. Vases and similar objects toppled over.
Sieben	45	54	112	8	6	Small house strongly shaken.
Wolf Creek	47	1	112	4	5+	Chandeliers swung.
Drummond	46	40	113	8	5+	House shook. Hanging lamps swung.
Great Falls	47	30	111	17	5	Chandeliers swung. A few vases, etc., toppled over. Buildings swayed perceptibly.
Neihart	46	15	110	43	5+	Loose articles moved but did not topple over. Bricks fell from an old chimney.
Belt	47	22	110	56	5	Hanging lamps swung. Posts, etc., swayed. An old cracked chimney thrown down.
Barker	47	4	110	37	5	Buildings swayed.
Monarch	47	6	110	50	5	Posts swayed. Loose articles moved.
Cascade	47	15	110	42	5	Loose objects moved. A few articles fell from shelves.
Anaconda	46	7	112	57	6	Buildings swayed; some loose bricks fell. Some dishes and vases overturned. Automobiles in garage moved back and forth. Water splashed out of pail. A "dead" motor on railway track moved.
Philipsburg	46	20	113	18	6	Buildings swayed alarmingly. Some plaster cracked and loose bricks shaken from tops of some walls. Courthouse clocks stopped at 6.22 p. m.
Columbus	45	38	109	15	6	Felt by nearly everyone. Some foundations settled and some chimneys toppled.
Hutchens's, 32 miles south of Ennis.	44	51	111	37	5	Hanging pictures shifted awry.
Gardiner	45	3	110	44	5	Strong shock. Hanging lamps, etc., swung.
Missoula	46	53	114	0	5	Felt generally. Hanging lamps swung moderately. A few cracks in plaster.
Superior	37	12	114	59	4	Chandeliers swung. Walls creaked. Felt distinctly for several seconds.
Roundup	46	27	108	34	5	Felt by nearly everyone indoors and out. Lamps swung. Loose objects moved.
Fort Benton	47	50	110	41	4	Felt by several persons outdoors. Loose objects moved. Frame building creaked. Shocks came at 6.30 and 7.30 p. m.
Grangeville, Idaho	45	50	116	8	4	Felt by many persons. Houses creaked and bed "wiggled."
Moscow, Idaho	46	42	117	0	4	Hanging lamps swung. Loose objects moved or rattled. Two water-pipe connections broken.
Shelby	48	30	111	52	4	Felt generally. Hanging lamps and pictures swung. Windows rattled.
Havre	48	33	109	40	4	Felt by nearly everyone. Pendulous objects swung. Doors and windows rattled.
Cody, Wyo	44	33	109	3	4	Felt generally by persons indoors. Hanging lamps, etc., swung.
Salmon, Idaho	45	10	113	53	4+	Felt by everyone. Loose objects moved or rattled. Lamps swung.
Mackay, Idaho	43	56	113	37	3+	Noticed by several persons indoors. Chandeliers swung and windows rattled.
Nezperce, Idaho	46	12	116	15	3	Noticed by several persons indoors. Windows, etc., rattled slightly.
Pullman, Wash	46	44	117	11	3	Noticed by several persons indoors. Windows rattled.
Malta	48	22	107	52	------	Noticed by several persons indoors. Hanging lamps swung.
Challis, Idaho	44	30	114	14	4	Noticed by nearly everyone indoors. Hanging lamps swung and windows rattled.
Dubois, Idaho	44	10	112	15	3	Felt by several persons indoors.

Intensity and effects of Montana earthquake of June 27, 1925—Continued

[Principal shock at 6.21 p. m.]

Place	Latitude N.		Longitude W.		Intensity	Effects, etc.
	°	′	°	′		
Lethbridge, Alberta	49	43	112	52	3+	Felt by persons indoors only. Clock in Canadian Pacific Ry. station stopped at 6.23 p. m. Shock lasted 30 seconds. Lights and hanging objects in hardware store swayed. Flower pots fell from a window ledge. A piano moved perceptibly. Clocks stopped. A second shock about 6.45 p. m.
Macleod, Alberta	49	44	113	23	3+	Felt by many persons, some of whom were outdoors. Hanging objects swayed and windows rattled. Shocks came about 6 and 7 p. m.
Forsyth	46	16	106	38	4	Felt on ground floor. Caused dizziness. Loose objects moved or rattled.
Baker, Oreg	44	47	117	52	3	About 5.25 p. m. (=6.25, mountain time). Felt by several persons indoors only. Chains and saws in hardware store rattled. Time of "regulator" clock in jewelry store was slowed down 2 minutes.
Colfax, Wash	46	54	117	24	3	Felt by several persons indoors only. Windows rattled. A bench and a bed moved perceptibly.
Medicine Hat, Alberta	50	0	110	40	2+	Felt by several persons indoors only. Hanging lamps swayed slightly. Persons sitting in chairs felt a swinging motion. Clock in Canadian Pacific Ry. station stopped at 6.23 p. m.
Cardston, Alberta	49	11	113	20	3	Felt by several persons, some of whom were outdoors. Shock composed of two tremors. Furniture moved "nervously." Some persons became ill.
Maple Creek, Saskatchewan	49	55	109	27	2+	Felt by several persons, some of whom were outdoors.
Swift Current, Saskatchewan	50	17	107	49	2	Felt by several persons indoors only. Slight on ground floor. Fairly distinct on upper floors. Dishes rattled in an apartment on the fourth floor.
Glacier Park	48	26	113	12	3	Felt by most persons indoors. Hanging lamps swung slightly.
Wibaux	46	59	104	11	2+	Felt by a few persons indoors and on upper floors. A rocking sensation like that caused by ocean waves. Windows rattled.
Casper, Wyo	42	52	106	17	2	Felt on fifth floor. Loose objects rattled.
Lewiston, Idaho	46	23	117	1	2+	Felt by a few persons indoors only. Loose objects rattled slightly.
St. Anthony, Idaho	43	58	111	43	2	Felt by several persons indoors only.
Weiser, Idaho	44	15	116	58	3	Felt by a few persons indoors. Lamps swung and loose objects rattled.
Warm Springs	46	11	112	47	6	Some brick veneering fell and some walls cracked.
Hamilton	46	15	114	10	5+	Some merchandise shaken from store shelves. Some plaster cracked. People rushed out.
Kalispell	48	12	114	17	3+	Shocks lasting 10 seconds at 6.20 and 7.10 p. m.
Dillon	45	14	112	38	6+	Some plaster fell and some dishes broken. People alarmed and ran out.
Lima	44	38	112	36	5+	At 6.23 p. m. People ran out of doors.
Miles City	46	24	105	51	3+	At 6.26 p. m. Pictures and chandeliers swung. Some persons ran out of doors. A second shock at 7.07 p. m.
Boise, Idaho	43	37	116	12	2+	At 6.23 p. m. Slight alarm on upper floors of hotels.
Sheridan, Wyo	44	48	106	54	3+	Small shock. Felt in several widely scattered localities. Time, 6.23 p. m.
Thermopolis, Wyo	43	38	108	12	3±	Light shock at 6.35 (6.25?) p. m.
Southern Cross	46	12	113	15	5+	Water in a pool splashed up in the face of a man drinking. A large rock loosened and rolled down hill. Trees waved from side to side.
Billings	45	47	108	30	6	Cracks opened in some old brick buildings. Some old wood-block paving buckled. Mild panic.
Spokane, Wash	47	40	117	25	2+	Registered on seismograph of Gonzaga University at 5.25 p. m. (6.25, mountain time). Felt in homes and downtown office buildings.
Sand Point, Idaho	48	17	116	32	3	Tremors felt lasting 2 or 3 minutes.
Bonners Ferry, Idaho	48	42	116	20	3	Do.
St. Maries, Idaho	47	19	116	33	3	Do.
Carmangay, Alberta	50	5	113	6	3	Shock lasted 15 to 30 seconds. Rocking motion felt upstairs in a 1½-story house.
Taber, Alberta	49	39	112	8	3	Shock lasted 3 or 4 seconds. Lights suddenly swayed. A counter in a store swayed forward and back. A house swayed gently.
Calgary, Alberta	51	4	114	5	2	Felt by persons in high buildings only. Clocks stopped at 6.28 p. m.
Moose Jaw, Saskatchewan	50	24	105	32	2	Felt by several persons. Dishes danced on a table on the fourth floor. Elevator, which had stopped at the same floor, was made by the shock to move up 2 feet. Four distinct shocks reported.
East End, Saskatchewan	49	35	108	50	2+	Clock in Canadian Pacific Ry. station stopped at 6.23 p. m.
Assiniboia, Saskatchewan	49	41	106	0	3	Distinct. Shock lasted 8 seconds.

Negative reports were received from the following places:

	Latitude N.		Longitude W.	
	°	′	°	′
Regina, Saskatchewan	50	27	104	35
High River, Alberta	50	35	113	52
Rossland, B. C	49	4	117	37
Cranbrook, B. C	49	30	115	46
Culbertson, Mont	48	9	104	31
Plentywood, Mont	48	46	104	35
Baker, Mont	46	23	104	15
Ekalaka, Mont	45	53	104	33
Sundance, Wyo	44	24	104	20
Newcastle, Wyo	43	52	104	10
Lander, Wyo	42	50	108	43
Evanston, Wyo	41	15	110	57
Kemmerer, Wyo	41	48	110	32
Green River, Wyo	41	32	109	28
Paris, Idaho	42	13	111	24
Montpelier, Idaho	42	18	111	18
Preston, Idaho	42	6	111	39
Twin Falls, Idaho	42	34	114	49
Gooding, Idaho	42	56	114	43
Rupert, Idaho	42	37	113	41
Idaho Falls, Idaho	43	29	112	4
American Falls, Idaho	42	47	112	53
Shoshone, Idaho	42	56	114	24
Blackfoot, Idaho	43	11	112	21
Pocatello, Idaho	42	52	112	26
Hailey, Idaho	43	30	114	18
Silver City, Idaho	43	0	116	42
Council, Idaho	44	44	116	25
Logan, Utah	41	45	111	50
Brigham, Utah	41	30	112	1
La Grande, Oreg	45	20	118	7
Enterprise, Oreg	45	25	117	18
Pomeroy, Wash	46	28	117	42
Walla Walla, Wash	46	4	118	22
Dayton, Wash	46	17	117	59
Rawlins, Wyo	41	47	107	14

DIRECTION OF THE MOTION

Positive evidence as to the direction in which the vibrations traveled is given by the operator of the Chicago, Milwaukee & St. Paul Railway at Jefferson Island. He was working on the train dispatcher's telephone at the time and heard the operator at Three Forks say they were having an earthquake. In a few seconds he felt it himself, and still later he heard it reported by the operator at Butte. In a straight line Three Forks is 20 miles east of Jefferson Island and Butte 30 miles to the west. Near Toston during the earthquake an observer in an automobile traveling on a road leading southeastward, or toward the epicenter, noticed nothing unusual in the behavior of his car. Another traveling in a northeasterly direction had difficulty in keeping his car on the road, presumably because he was traveling crosswise to the direction of motion. Many of the observers reported the direction that the earthquake waves seemed to travel, and most of these directions, whether leading toward or away from the epicenter, when platted on the map, coincide nearly with radii.

NATURE OF THE MOTION

Observers near the epicenter describe the earthquake motion as a violent bumping and rocking. Elsewhere practically all describe it as a rocking motion, which a few qualify with the terms bumping, jerking, or twisting. Visible ground waves, much like the swell in the wake of a steamboat, were reported by many persons. Similar waves were indicated by the behavior of buildings, fences, telegraph poles, etc., which were observed to lean to one side and then to the other, describing arcs of as much as 30°. Standing automobiles, including a heavy tractor, were seen to dance a comical sort of jig, rising first on one side then on the other. At Three Forks a frame house appeared to buckle up along the comb of the roof, like a cat humping its back at sight of a dog, and then straighten out again without being seriously damaged. At Willow Creek an observer was able to see clear under a house momentarily as one end lifted clear of the foundation and settled back to place.

At Radersburg, Logan, and other places some chimneys were broken at the roof line and twisted clockwise one-eighth to one-quarter of a revolution (pl. 13, *B*).

SOUNDS

Sounds of low pitch were heard by 80 per cent of the observers who were within 25 miles of the epicenter, and by 65 per cent of those within 80 miles. Beyond that distance only 30 per cent of the observers report sounds, but information from this outlying belt is too scanty to fix the limit of the sound area. The great majority of the observers describe the sounds as a low rumbling, and several add that it was like a train or a heavy truck passing by or crossing a bridge, or like thunder. A few describe the sound as a roaring, a rushing or swishing like the wind, or like a storm or a low growl.

AREA

The area throughout which the shock was sensible to persons, which is the area bounded by isoseismal 2 (see pl. 3) is about 310,000 square miles. The disturbed area is therefore of about the same order of magnitude as that of tectonic earthquakes of the first rank. The intensity of the Montana disturbance was apparently somewhat less than that of the California earthquake of 1906, and the damage, owing, as already explained, to the lack of populous cities near the epicenter, was comparatively insignificant.

TIME AND DURATION

The time at which the main shock occurred is reported variously from 6.15 to 6.35 p. m., but 70 per cent of the observers set the time between 6.20 and

6.25 p. m. Of those who were within a radius of 50 or 60 miles from the epicenter 60 per cent reported the time as either 6.20 or 6.21 p. m., the weight of evidence, all things considered, being much in favor of 6.21. Clocks stopped at that time in a drug store at Three Forks and in the office of the United States Weather Bureau at Helena. Outside the area described, 12 observers out of a total of 24 place the time at 6.23 and 4 at 6.25; the remainder are scattering.

Estimates of duration reported by 66 persons range from 5 seconds to 3 minutes, but about three-fourths of the estimates lie between 15 seconds and 1 minute, and their average is about 30 seconds. No one reported having timed the shock with a watch or other instrument, but within the area of startling shock the duration was at least 15 or 20 seconds, for in less time the observers could hardly have traversed the distances or performed the tasks that they claimed to have done while the shaking was in progress. Apparently in outlying areas where the intensity was moderate or feeble the sensible vibrations continued for 30 seconds or more.

SPEED OF TRANSLATION

Clocks in Canadian Pacific Railway stations at Lethbridge and Medicine Hat, Alberta, and East End, Saskatchewan, stopped at 6.23 p. m. A Western Union clock at Glasgow, Mont., was reported stopped also at that time. The distance of these places from the epicenter ranges from 264 miles for Lethbridge to 276 miles for Medicine Hat. If the times as given for these places and for the epicenter are accepted as correct, then the vibrations were propagated outward an average distance of 270 miles in two minutes, or at the rate of 2¼ miles a second. Owing to the fact, however, that the time observations were made to the nearest minute only, there remains the possibility of an error as great as one minute, plus or minus. Therefore, the total time of translation for the distance mentioned may be as short as one minute or as long as three minutes, and the speed at which the vibrations traveled lies between 4½ and 1½ miles a second.

ISOSEISMALS [5]

DATA AVAILABLE

Compared to the size of the disturbed area the number of observations available is rather small, and therefore the isoseismal lines as drawn (pl. 3) doubtless appear more precise and definite than they should. Where their position is believed to be determined within rather narrow limits they have been drawn as full lines; where the evidence for placing them is less definite, they are represented by dashes.

Isoseismal 9 is perhaps determined with more certainty than any of the others. It incloses Three Forks, Manhattan, Logan, Toston, and other places where the earthquake effects were most conspicuous and abundant. The central part of this area is thinly inhabited and almost devoid of structures that would be easily damaged by earthquake shocks. If the effects on similar things are compared, however, the intensity seems to have been considerably higher in this central area than at Three Forks and the other places mentioned. Accordingly, an isoseismal provisionally labeled 10 has been drawn inclosing an area of about 80 square miles in Clarkston Valley and the adjoining hills on the east and north. Lombard, the largest settlement within this isoseismal, contains two railroad stations of one-story frame construction with brick chimneys and eight or ten small frame houses, some of which are merely converted box cars. Clarkston consists of a station, a grain elevator, and two or three small houses. Cardinal and Deer Park each have two or three small buildings. The remainder of the area contains only a few small houses of frame or log construction. None of these buildings was very seriously damaged, though they plainly show the effects of severe shaking. All chimneys were overthrown and plaster was broken in the few houses that possessed such features. Commonly door, window, or house frames were sprung or distorted. Some log cabins and barns were noticeably sprung out of shape or made to lean to one side. Some doors were jerked off their hinges. Furniture, including stoves and ranges, and other loose articles were overturned or thrown about, and in most houses practically every dish or other breakable article was demolished. The racking a small but substantial unplastered frame house at Cardinal suffered is shown by torn wall paper and lining. The intensity of the shock at Roy Gulch is indicated by the cracking and shattering of moderately firm ground and the overturning of clods (pl. 12, *B*). At Garden Gulch an observer saw the clods in a plowed field shuffled about like checkers being shaken on a board. Rock falls in this area have been described (pp. 9–10).

At Three Forks and other places outside the area being considered the overthrowing of furniture and the breaking of dishes were less general or complete and the springing or racking of door and house frames was rather exceptional. The crack that appeared in the road north of Three Forks opened in an artificial embankment not to be compared in resistance to the firm ground which was shattered at Roy Gulch. At Trident there are cliffs essentially similar to those at Lombard, but much less material was shaken down from them.

So far as the evidence goes, therefore, the shock appears to have been much stronger in this central

[5] "An isoseismal line, or simply an isoseismal, is a line drawn through all places at which the intensity of the shock is the same."—Davison, C., A manual of seismology, p. 4, Cambridge Univ. Press, 1921.

area than elsewhere. After comparing effects in the field it is difficult to escape the conclusion that had a town such as Three Forks, for example, been situated here every brick building in it would have been leveled.

POSITION OF THE EPICENTER

The longer axis of the innermost isoseismal trends about N. 10° E. and lies a little east of Cardinal, crossing the lower parts of Roy and Garden Gulches. Its position is not far from a line dividing T. 4 N., R. 3 E., into east and west halves. The longer axis of the next isoseismal (No. 9) is parallel to that of the smaller curve, but it lies about a mile farther west. As nearly as can be determined, therefore, the epicenter lies either on one of these axes or between them and within a belt extending south 3 or 4 miles from Cardinal.

FORM OF THE ISOSEISMALS

As drawn isoseismal curves 7, 8, and 9 show a tendency to expand toward the west; possibly this is an erroneous interpretation, due to the lack of sufficient data or to undue weight having been given to the evidence from the more populous areas. Such a result has been guarded against as far as possible, however, and the expansion is believed to be real. It may possibly be due to the westward hade of the fault on which the earthquake is supposed to have originated, (see p. 22).

The three outer isoseismals show a striking irregularity at the south, where they are crowded inward so as to exclude a wide reentrant from the area of sensible shock. St. Anthony, Idaho, near the peak of this reentrant, is only 150 miles south of the epicenter, whereas in other directions the shock persisted for distances of 300 to 400 miles. This abrupt and abnormal decline of intensity begins at the edge of the Snake River Plain, a great valley floored with lava. Presumably the lava overlies a considerable thickness of unconsolidated sediments, and these in turn rest upon the upturned and eroded edges of older and harder rocks like those of the surrounding mountains. At the northeast the lava of the Snake River Plain merges with the lavas of Yellowstone Park, which consist of a great thickness of flows, tuffs, and breccias. The whole forms a heterogeneous mass that coincides suggestively with the zone in which the southward progress of the vibrations was arrested. At the west a similar indentation is indicated where the disturbed area touches the Columbia Plateau, but only isoseismals 2 and 3 are affected. Here the vibrations persisted somewhat beyond the edge of the lava, but there was a sudden and marked decline of intensity as soon as the main lava area was reached.

Columbia Plateau is made up of many lava flows, between some of which are beds of gravel or silt, the whole forming a mass of similar physical character to the rocks of the Snake River Plain and Yellowstone Park. It would seem, therefore, that these rather loosely aggregated masses were able to break up and check the rather feeble vibrations that reached them. This explanation, however, becomes less certain when the fact is considered that toward the northeast the vibrations extended farther than anywhere else, though the region they traversed is underlain by rocks (Cretaceous sediments) that are not especially dense or homogeneous.

Both the Snake River Plain and the Columbia Plateau may be regarded as great structural depressions, and it is possible, therefore, that the vibrations were cut off or deflected by bordering fault zones, but there are many similar though smaller structural features within the disturbed area that do not seem to have hindered the tremors at all.

FORESHOCKS

Although 80 per cent of the observers report the onset of the main shock as rapid or abrupt, without any warning, the remainder felt a preliminary quiver which, according to several persons, was separated from the main shock by a brief pause. Reports of this preliminary tremor which may possibly be classed as a foreshock, were obtained at places well distributed through an area measured by a radius of 125 miles from the epicenter. Doubtless the failure of most observers to notice it was due to lack of experience. Many of the shocks that were rather generally observed after June 27 were probably of no greater intensity.

An interesting foreshock occurred May 31, reports of which were obtained from five observers. At Lombard this shock, as timed by J. P. Swarts and W. P. Luburg, Northern Pacific Railway operators, occurred at 7.55 a. m. Loose articles in a small frame house (a converted box car) moved or rattled, and a doorframe was sprung slightly. At the same time another observer, Arthur Jersey, who was walking in the hills 3 miles northwest of Sixteen, felt a shock in which the ground seemed to rise suddenly and then settle back and quiver a little. At Menard the same shock, as reported by Mrs. A. R. Hill, made things rattle, and according to W. T. Lathrop, two light shocks were felt in the office of the United States Weather Bureau (sixth floor) at Helena, and in a residence at Kenmore. Lombard is a short distance northwest, Menard 12 miles southeast, Sixteen 20 miles northeast, and Helena about 50 miles northwest of the epicenter of the earthquake of June 27. Apparently the shock of May 31 emanated from the same center.

AFTERSHOCKS

A great many aftershocks were felt at Three Forks, Manhattan, and other places near the epicenter, and several of them were perceptible also at more distant points. The ground is said to have been in an almost continuous tremble during the night of June 27 at Lombard, Deer Park, and similarly situated places. At Trident sensible shocks are estimated to have averaged four a day for the first month and two a day for the second month after the earthquake. Between June 27 and July 6 a record was kept by A. D. Burkett of 52 shocks that were strong enough to be felt by nearly everyone. The total number of aftershocks recorded prior to August 14 is about 75.

The strongest aftershock and the first one to be generally observed occurred at 7.10 p. m., or about three-quarters of an hour after the main shock. It was more or less distinct over a large area, most of the observers in which describe it as being nearly, if not quite, as strong as the main shock but of somewhat shorter duration. It caused additional rock falls, threw down some more chimneys, and caused many brick walls that had been loosened by the first shock to topple over. It came on very abruptly, accompanied by a deep rumble or roar, and caused renewed and increased alarm among the inhabitants.

This shock was felt at Miles City, 270 miles east, at Macleod, Alberta, 270 miles north, and at Kalispell, 200 miles northwest of the epicenter. On the south the most distant point reporting it is Hutchens, on Madison River, 75 miles from the epicenter. There the intensity was between 3 and 4. The shock is thus indicated to have been sensible throughout an area of nearly 200,000 square miles. The available records are tabulated below:

Summary of reports of aftershock of the Montana earthquake of June 27, 1925, occurring at 7.10 p. m. mountain time

Place [a]	Latitude N.		Longitude W.		Intensity	Remarks
	°	′	°	′		
Townsend	46	20	111	32	8	Clock stopped 7.10 p. m. Duration 30 seconds. Almost as strong as first shock.
Deer Park	46	8	111	9	9+	Short but so violent persons could not stand alone.
Dave Johnson's, 3 miles north of Cardinal.	46	9	111	21	9	Shorter than first shock.
Stockburger's, 2½ miles northeast of Cardinal.	46	8	111	20	9+	Seemed longer than first shock.
Butte	46	0	112	33	5±	Duration 40 seconds.
Logan	45	53	111	26	9+	Seemed harder than first shock. Bricks fell at schoolhouse.
Manhattan	45	52	111	20	9+	A sudden hard shock. Observer could not keep feet or reach door. Most of the fallen brick at schoolhouse came down at this time.
Three Forks	45	53	111	53	9+	Abrupt and harder than first shock but shorter. Some persons standing were thrown down. Most of the brick fell from church at this time.
Trident	45	57	111	29	9+	Seemed stronger than first shock.
Roy Stillman's, 7 miles southwest of Maudlow.	46	4	111	17	9+	Abrupt but shorter than first shock.
Jacobs's, 7 miles southeast of Townsend.	46	15	111	22	8±	Shorter than first shock.
Clarkston	46	2	111	24	8±	Do.
Perugin's, 9 miles southeast of Townsend.	46	15	111	22	8±	Shorter than first shock. In two phases.
Belgrade	45	2	111	11	8±	At 7.15 p. m. Many bricks came down. One observer says it was more violent than first shock; another observer who was in a moving automobile on a slippery road did not feel the shock.
Willow Creek	45	50	111	39	8±	Shorter than first shock, but trees swayed as if they would snap off. House raised clear off foundation on one side and came back to place.
Walbert's, 9 miles north-northwest of Three Forks.	46	2	111	38	7±	Shorter than first shock.
Radersburg	46	13	111	39	7±	Do.
Menard	45	48	111	12	7±	Do.
Maudlow	46	8	111	10	7±	Shorter than first shock. Did not shake as many goods from shelves as first shock, but more bricks came down.
3 miles south of Manhattan	45	50	111	20	8	This shock turned upper part of brick chimney one-eighth revolution clockwise and threw dishes from shelves.
Mockel's, 7 miles south-southeast of Radersburg.	46	8	111	36	7±	
Helena	46	36	112	0	5±	Strong vibration of several seconds at 7.07 p. m., but shorter and weaker than first shock.
Whitehall	45	48	112	6	?	Shorter than first shock.
Jefferson Island	45	47	111	57	6±	Do.
Bozeman	45	41	111	3	6±	Automobile moved forward and back. Flagpole swayed east and west.
White Sulphur Springs	46	33	110	54	6±	
Fort Logan	46	42	111	11	6±	Weaker than first shock.
House's, 10 miles northeast of Bozeman.	45	50	110	53	6±	Buildings swayed.
Clyde Park	45	53	110	37	7±	Seemed harder than first shock.
Norris	45	34	111	42	?	Half as long as first shock.
Harrison	45	42	111	48	7+	Seemed about as hard as first shock but shorter. Kitchen cabinet flew open and dishes spilled. Seemed harder than first shock to one observer.

[a] In Montana except as otherwise indicated.

Summary of reports of aftershock of the Montana earthquake of June 27, 1925, occurring at 7.10 p. m. mountain time—Continued

Place	Latitude N.		Longitude W.		Intensity	Remarks
	°	′	°	′		
Twin Bridges	45	33	112	20	5	Seemed lighter than first shock. Fence swayed strongly.
Butte	46	0	112	33	5±	40 seconds.
Drummond	46	40	113	8	4±	
Great Falls	47	30	111	17	4±	Some movement of dishes, but none fell.
Neihart	46	56	110	43	3–4	Scarcely felt by persons out of doors.
Belt	47	22	111	56	4±	Part of a dry stone wall fell.
Anaconda	46	7	112	51	5±	About like first shock.
Philipsburg	46	20	114	18	5±	Fence swayed back and forth. Seemed harder than first shock to one observer.
Hutchens's, on Madison River	44	51	111	37	3–4	Felt distinctly.
Superior	47	12	114	59	2±	Weaker and shorter than first shock.
Macleod, Alberta	49	44	113	23	2	About 7 p. m.
Miles City	46	24	105	51	2±	At 7.07 p. m. Lamps swung.
Kalispell	48	12	114	17	2±	At 7.10 p. m.; 10 seconds.
Missoula	46	53	114	0	------	At 7.06 p. m.
Hardin	45	49	107	37	------	At 7.07 p. m.
Billings	45	47	108	30	3±	At 7.07 p. m.; 20 seconds.
Lethbridge, Alberta	49	43	112	52	2	About 6.45 p. m.
Pine Grove	46	49	109	4	------	At 7.05 p. m. Stronger than first shock.
Big Timber	45	50	109	53	------	At 7.00 p. m.
Busteed	45	53	109	22	------	At 7.10 p.m.
Findon	46	37	110	22	------	Do.
Hebgen Dam	44	51	111	20	------	At 7.05 p. m.
Hobson	47	0	109	50	------	At 7.10 p. m. Duration, 10 seconds.
Flatwillow	46	50	108	24	------	At 7.15 p. m.
Ovando	47	2	113	7	------	At 7.00 p. m.
Stevensville	46	31	114	7	------	At 7.05 p. m.

As nearly as can be determined the epicenter of the shock at 7.10 p. m. is a short distance south of the epicenter of the main shock.

Additional aftershocks up to August 13 were recorded as follows, including the 52 shocks reported by A. D. Burkett at Trident:

Aftershocks from June 27 to August 13

Time	Places reporting	Indicated size of area disturbed (square miles)
June 27, 8.35 p. m.	Stevensville, Helena, Anaconda, Billings (8.37), Big Timber (8.40)	50, 000
June 27, between 9.20 and 9.41 p. m.	Conway, Philipsburg, Helena, Anaconda (violent)	17, 000
June 27, between 10.25 and 10.30 p. m.	Anaconda, Helena, Philipsburg, Trident (heavy)	17, 000
June 27, between 10.39 and 10.40 p. m.	Livingston (set light bulbs swaying), Trident (heavy), Helena	7, 500
June 28, between 1.55 and 2.00 a. m.	Trident (heavy), Philipsburg	17, 000
June 28, 2.20 a. m.	Trident (heavy)	----------
June 28, 3.00 a. m.	Philipsburg	----------
June 28, between 3.30 and 3.33 a. m.	Conway, Hebgen dam	----------
June 28, 4.42 a. m.	Trident (heavy)	----------
June 28, 5.14 a. m.	Helena (distinct, 2 or 3 seconds)	----------
June 28, 6.05 a. m.	Trident (moderate)	----------
June 28, 8.39 a. m.	Trident	----------
June 28, 11.00 a. m.	Trident	----------
June 28, between 3.30 and 3.38 p. m.	Helena (light), Manhattan (heavy), Trident, Bozeman, Livingston	7, 500
June 28, 10.30 p. m.	Helena	----------
June 28, 10.53 p. m.	Trident	----------
June 29, 12.30 a. m.	do	----------
June 29, 2.02 a. m.	Trident (very noticeable in quarry; rock falls)	----------
June 29, between 2.25 and 2.30 a. m.	Trident (shook town from one end to the other), Helena (sharp; 7 seconds), Great Falls (several seconds; dishes and pictures moved), Billings, Philipsburg.	50, 000
June 29, 4.10 a. m.	Trident (small)	----------
June 29, 4.30 a. m.	Helena	----------
June 29, 8.00 a. m.	Lombard	----------
June 29, 10.00 a. m.	Lombard	----------
June 29, 10.49 a. m.	Trident (moderate)	----------
June 29, 5.39 p. m.	Trident (heavy)	----------
June 29, 10.16 p. m.	Trident	----------
June 29, 10.30 p. m.	Bozeman	----------
June 29, between 11.30 and 11.35 p. m.	Helena, Livingston, Philipsburg, Trident (very noticeable in kiln room), Bozeman.	30, 000

Aftershocks from June 27 to August 13—Continued

Time	Places reporting	Indicated size of area disturbed (square miles)
June 30, 2.44 a. m.	Trident (one shock)	
June 30, 2.48 a. m.	Trident	
June 30, 11.13 a. m.	Trident (light)	
June 30, 3.45 p. m.	Trident	
July 1, 7.26 a. m.	do	
July 1, 7.45 a. m.	Trident (light, but nearly steady for 15 minutes)	
July 2, 2.25 a. m.	Trident	
July 2, 2.50 a. m.	Trident (long and steady, but not very severe)	
July 2, 3.15 a. m.	Trident	
July 2, 3.48 a. m.	Trident (long and steady, but not very severe)	
July 2, 8.15 a. m.	Trident	
July 2, 8.24 p. m.	do	
July 3, 1.25 a. m.	Trident (light; 3 minutes)	
July 3, 2.30 a. m.	Trident (one sharp shock)	
July 3, 8.27 a. m.	Trident (intermittent shocks)	
July 3, 10.00 p. m.	Trident (six shocks)	
July 3, 11.00 p. m.	Trident (weak shocks lasting nearly an hour)	
July 4, 2.25 a. m.	Trident (single distinct shock for ½ minute)	
July 4, 4.00 a. m.	Trident (six light, distinct shocks)	
July 4, 9.04 p. m.	Trident (one shock)	
July 4, 10.20 p. m.	Trident (six light shocks, one stronger shock)	
July 4, 10.30 p. m.	Trident (one sharp shock, noticeable in packing house)	
July 5, 2.10 a. m.	Trident (sharp shock)	
July 5, 2.17 a. m.	Trident (one light shock)	
July 5, 2.21 a. m.	do	
July 5, 2.40 a. m.	Trident (three light shocks)	
July 5, 4.47 a. m.	Trident (intermittent bumping shocks lasting 3 minutes)	
July 5, 6.16 a. m.	Trident (heavy and apparently of deep-seated origin, rounding waves, lasting 2 minutes).	
July 5, 10.26 p. m.	Trident (very noticeable in transformer building)	
July 6, 1.58 a. m.	Trident	
July 6, 8.10 a. m.	Trident (heavy)	
July 6, 9.17 a. m.	do	
July 6, 10.15 a. m.	do	
July 6, 11.46 p. m.	Trident (very noticeable in packing house)	
July 10, 12.00 a. m.	Helena	
July 10, 5.00 a. m.	do	
July 10, 6.00 a. m.	do	
July 10, between 7.42 and 7.48 a. m.	Anaconda (30 seconds; in two parts with a pause between), Deer Lodge, Bozeman, Missoula (intensity 2–3), Great Falls (3 seconds; intensity 3–4), Billings (intensity 2), Three Forks (loose bricks fell; intensity 6), Manhattan (intensity 6), Trident (stiff shock; 30 seconds), Helena (10 seconds), Cardinal (intensity 6–7), Logan, Livingston, Willow Creek, Butte.	50, 000
July 10, 2.00 p. m.	Helena (very slight)	
July 20, between 10.05 and 10.07 a. m.	Missoula, Great Falls (slight)	
July 22, 4.53 p. m.	Lombard (light)	
July 24, 2.55 p. m.	Trident (light)	
Aug. 12, 8.10 p. m.	Trident (strong; 5 seconds; ground waves)	
Aug. 13, 1.30 a. m.	Trident (strong)	
Aug. 13, 3.30 a. m.	do	
Aug. 29, 8.00 a. m.	Lombard	
Aug. 29, 10.00 a. m.	Cardinal (upset bottles, etc.; rocks fell; three light shocks the following night), Menard (strong), Lombard (very severe), Trident, Logan.	1, 000
Sept. 3, 2.00 a. m.	Menard (caused a bottle to tip over)	

Shocks reported from Helena by the Associated Press occurred September 19 at 3.45 a. m. (sharp, short), September 30 at 2.30 a. m. (caused snow slides from roofs), and early in the day of October 6 (short, sharp). These also are doubtless to be classified as aftershocks of the earthquake of June 27, but reports of them from places nearer the epicenter are lacking.

PHYSIOGRAPHY AND GEOLOGY OF EPICENTRAL AREA

SURFACE FEATURES

The area within isoseismal 10 includes a lowland along Missouri River at Clarkston and parts of the hills that adjoin it on the east and north (pl. 4). The lowland, which will be referred to herein as Clarkston Valley, is a depression about 10 miles long and 5 or 6 miles across at the middle and widest part. It is bordered on the east by the moderately steep Horseshoe Hills, 1,000 to 3,000 feet high, which are in fact the extreme northern part of the Belt Mountains. At the north and south are broad spurs extending west from the Horseshoe Hills, and at the west is an unnamed range of hills of somewhat less elevation. Together the hills and ridges described form a surrounding wall that is broken at three places only, each opening being a narrow stream-cut valley or gorge. At the northeast is the gorge of Sixteenmile Creek, in which the Deer Park slide occurred. At the south, at Trident, is a narrow, steep-sided valley that admits Missouri River, and at the north, beginning at Lombard, is a deep, narrow, and crooked gorge, known as Horseshoe Bend, through which the river escapes.

Clarkston Valley consists of a strip of level bottom land along the river and a larger area of rather low terraces or bench lands. The terraces, which are generally known throughout this region as "benches," are remnants of stream-cut plains that were developed at higher levels and at an earlier period than the plain that now forms the valley bottom. They are due to the downcutting of streams, and it follows that most of them surmount the divides between stream courses that lead from the mountains to the river. Their fronts or edges are steep descending slopes or scarps, and their tops are smooth plains that rise gradually toward the mountains. In the gorges at Trident and Lombard and here and there along the west side of Clarkston Valley are small benches 40 or 50 feet higher than the bottom lands.

On the east side of the valley the benches occupy the greater part of an area about 3 miles wide that adjoins the mountains and extends the full length of the valley. Here the fronts or scarps of the benches are mostly 100 to 150 feet high, and their tops slope upward toward the mountain with a gradient of about 300 feet to a mile. Near the mountains this slope is increased slightly, but not enough to mask the point at which a definite and rather abrupt change to the steeper slope of the mountain takes place (pl. 4).

STRATIGRAPHY

Rocks ranging in age from pre-Cambrian to late Mesozoic (Cretaceous) form the surrounding mountains and hills and, within Clarkston Valley, probably constitute a bedrock floor beneath the Tertiary and later deposits. As shown by Peale,[6] the spur that incloses the valley at the south is composed chiefly of Paleozoic limestones with some sandstone and other beds of Paleozoic and Algonkian age. The same rocks continue northward, forming the hills east and west of the valley and the spur that bounds it on the north. North of Clarkston, near the middle of the valley, a hill of the Paleozoic limestones projects through the Tertiary beds like an island in a lake, and there is a similar occurrence farther northeast on the north side of Garden Gulch. North of Lombard sandstone, shale, and limestone of Cretaceous age are folded in with the Paleozoic rocks. Excellent sections of the rocks mentioned are exposed in the gorges of Missouri River and Sixteenmile Creek, and stratigraphic details of them are given by Campbell[7] and Haynes.[8]

[6] Peale, A. C., U. S. Geol. Survey Geol. Atlas, Three Forks folio (No. 24), 1896.

Beds of moderately hardened clay and weakly cemented sand and gravel, commonly known as Tertiary "lake beds," compose the "benches" and probably occur also beneath the alluvium of the valley bottom. They lie upon the upturned and eroded edges of the older rocks described and are in turn partly covered and concealed from view by gravel of Pleistocene and Recent age. They are correlated with the Oligocene and Miocene beds occurring a short distance to the north in Townsend Valley[9] and in the valleys of southwestern Montana generally.

STRUCTURE

The older rocks mentioned are involved in rather close folds that vary in trend from north to northeast and cause the beds in most places to be steeply inclined. The section at Trident shows an anticline that is overturned eastward and faulted.[10] In the neighborhood of Deer Park several faults of apparently small extent that trend northwestward are mapped by the geologists of the Anaconda Copper Mining Co.[11] Their age and displacement are not known. In the hills west of Missouri River is an overthrust fault, called the Lombard overthrust,[12] that extends from a point north of Three Forks northeastward for 13 miles or more. Its trace crosses Horseshoe Bend about a mile west of Lombard. There the fault dips about 40° W. and has brought Belt (Algonkian) rocks eastward over rocks of Cretaceous age. Beds that are stratigraphically 6,800 feet apart are in contact, and the maximum displacement is estimated at about 2 miles. The fault is younger than Lower Cretaceous (Kootenai) strata exposed near Lombard and probably older than the lower Oligocene beds described by Douglass.[13]

The only visible structural feature of the Tertiary beds is a persistent eastward dip of 10° to 20°. Owing to the fact that these beds break down rather easily under weathering, good exposures are few and are generally confined to very steep slopes or newly cut ravines. Hence it is possible that some minor folds or faults were overlooked, but there seems no doubt as to the prevailing eastward dip. At only one place north of Garden Gulch and within 100 feet of the area of older rocks were the Tertiary beds observed as

[7] Campbell, M. R., Guidebook of the western United States, Part A, The Northern Pacific Route: U. S. Geol. Survey Bull. 611, pp. 116–118, 1915.

[8] Haynes, W. P., The Lombard overthrust: Jour. Geology, vol. 24, pp. 269–290, 1916.

[9] Pardee, J. T., U. S. Geol. Survey Water-Supply Paper 539, pp. 17–34, 1925.

[10] Campbell, M. R., op. cit., p. 117, fig. 26.

[11] Unpublished map.

[12] Haynes, W. P., op. cit.

[13] Douglass, Earl, Fossil Mammalia of the White River beds of Montana: Am. Philos. Soc. Trans., new ser., vol. 20, pp. 238–279, 1902.

dipping westward. The boundary between the Tertiary and older rocks at the east edge of the valley is rather generally concealed by alluvium and deep surface mantle, but it holds a rather straight course and is not extensively deflected where it crosses gulches or ridges. Apparently, therefore, this boundary is the trace of a steeply pitching surface toward which the Tertiary beds are inclined. Such a relation is difficult to explain except as a result of faulting by which the Tertiary beds were relatively downthrown. This idea is supported by certain features of the valley itself. Clarkston Valley is a wide depression in deformed and eroded pre-Tertiary rocks. Its rim or surrounding wall is broken only by three narrow stream gorges. Such a basin could be formed in only two ways—by erosion or by structural movements. If due to erosion, it must have been an area of rocks that were softer and more easily eroded than the rocks in which the gorges were cut, which is evidently not true. Therefore there seems no alternative but to regard the valley as a relatively depressed or down-faulted area. The features of the Tertiary beds indicate that down faulting occurred along the east side of the valley during Miocene or later time, the pitch of the fault being toward the west.

Similar features are shown in Townsend Valley, a short distance to the north. There also the Tertiary beds rest in a basin depressed in the older rocks and show a persistent dip toward the east side of the valley. At the point where Sixmile Creek (which is about 4 miles north of Sixteenmile Creek) leaves the mountains the eastward-dipping Tertiary beds abut against the older rocks,[14] the relation being interpreted as due to a fault with the downthrow on the side next to the valley.

CAUSES OF THE EARTHQUAKE AND LOCATION OF THE FOCUS

The size of the disturbed area, the gradual decline of intensity away from the epicenter, and other features of the Montana earthquake indicate that it was the result of fault movements rather than of volcanic action. So far as observed in the neighborhood of the epicenter no new fault displacement is manifest at the surface. This may be explained by the fact that there is a thick superficial cover of rather soft sediments (Tertiary "lake beds"), in which a slip originating in the rocks below might be distributed and lost.

Of the faults previously mapped in this region the Lombard overthrust (p. 21) is too far from the epicenter to be considered. The faults mapped by geologists of the Anaconda Co. as crossing Sixteenmile Creek near Deer Park are not far from the epicenter, but their strike differs considerably from the course of the longer axis of the isoseismal curves. They cut Paleozoic rocks, and whether they are older or newer than the Tertiary beds is not known. The writer did not identify them, but owing to their location and trend he is inclined to believe that they do not contain the focus of the earthquake.

In the absence of positive evidence to the contrary it must be admitted that the earthquake may have originated along some fracture that has not yet been discovered or even suspected. All necessary conditions, however, are met by the assumption that the slip occurred in depth on the fault postulated as extending along the east side of Clarkston Valley. This fault is Miocene or younger and is probably still active.

The difference between the longer and shorter diameters of the inner isoseismal curves is from 6 to 10 miles, which presumably is of the same order of magnitude as the length of the focus or the distance along which slipping occurred. The extent of the area in which the shock was strong or destructive presumably indicates that the focus was moderately deep, perhaps several miles.

PROBABILITY OF FUTURE EARTHQUAKES

On the theory that the earthquake of June 27 with its succeeding aftershocks accomplished the relief of stresses that for some time had been accumulating a period of quiet may be expected so far as movement on the particular fault that caused the disturbance is concerned. The neighboring region, however, probably contains many other faults that are carrying unrelieved strains and may therefore become active at any time. Several of the mountain ranges of this region—Madison Range, for example—present high, steep fronts which suggest that they have been newly elevated and perhaps are still growing and therefore to be regarded as accumulating strains that will eventually result in earthquakes. Southwestern Montana is part of the Cordilleran region, which as a whole is a region in which rather severe earthquakes have occurred now and then in the past and are reasonably to be expected in the future.

In Montana prior to 1925 no destructive earthquakes have been recorded, but earlier than 50 or 60 years ago settlements here were so few and far between that strong shocks might have passed unnoticed. According to some of the pioneer residents a moderate earthquake was experienced in the Gallatin Valley in 1883 that threw dishes off shelves and awakened sleepers. In 1805 sounds that were probably of earthquake origin were noticed near the present site of Great Falls by members of the Lewis and Clark expedition. In his journal of June 18–20, 1805, Captain Clark[15] records that the men of the expedition first told him of hearing the sound for which he supposed they had mistaken distant thunder. On June 19, however, while walking on the plain above the falls he himself

[14] Pardee, J. T., U. S. Geol. Survey Water-Supply Paper 539, p. 32, 1925.

[15] Original journals of the Lewis and Clark expedition, edited by Reuben Gold Thwaites, vol. 2, p. 176, Dodd, Mead & Co., 1904.

heard the noise distinctly and paused, listening for two hours, during which time it was twice repeated. He describes it as an "unaccountable rumbling" and also as resembling distant artillery fire. It seemed to come from the west, was heard at irregular intervals, and consisted of a single discharge or of several discharges in quick succession. This description tallies closely with that of sounds called brontides,[16] which are regarded by authorities as partly at least of seismic origin—possibly the final representatives of a series of aftershocks.

It is probable, from the facts above set forth, together with the evidence of the recent earthquake, that the general region here considered is in a condition of moderate seismic activity and is likely to be visited by an occasional severe shock. It behooves the inhabitants, therefore, to take at least a few simple precautions toward the prevention of future damage. For example, the prevailing custom of laying up veneer or face brick without ties or bonding to fasten it to the back wall should be outlawed. The use of poor or insufficient mortar is of course to be condemned under any condition. Apparently a rich Portland cement mortar will make brick walls proof against shocks as severe as the recent one, and chimneys may be prevented from falling by a few braces of strap iron. Many of the towns are built on deposits of unconsolidated stream gravel, on which a shock is likely to be more destructive than on solid rock. This condition can be overcome, however, by making the foundations deeper and heavier than ordinarily is needed. It is evident that the wrecked schools at Three Forks and elsewhere could have been made earthquake proof when they were built, at a fraction of the cost it has taken to repair them. Apart from this there appears a more weighty consideration. When will the next earthquake come? When schools are in session or congregations assembled?

[16] Davison, Charles, A manual of seismology, pp. 63–65, Cambridge Univ. Press, 1921.

AMERICAN TERTIARY MOLLUSKS OF THE GENUS CLEMENTIA

By W. P. Woodring

INTRODUCTION

Aside from its value as an aid in determining the age of Tertiary beds, the chief interest of the genus *Clementia* lies in the anomalous features of its present and former distribution. An attempt is made in this paper to trace its geologic history, to point out its paleobiologic significance, and to describe all the known American Tertiary species.

The fossils from Colombia used in preparing this report were collected during explorations made under the direction of Dr. O. B. Hopkins, chief geologist of the Imperial Oil Co. (Ltd.), who kindly donated them to the United States National Museum. Dr. T. Wayland Vaughan, of the Scripps Institution of Oceanography, furnished information relating to specimens collected by him in Mexico. Dr. Bruce L. Clark, of the University of California; Dr. G. Dallas Hanna, of the California Academy of Sciences; Dr. H. A. Pilsbry, of the Philadelphia Academy of Natural Sciences; and Dr. W. D. Matthew, of the American Museum of Natural History, generously loaned type specimens and other material. Doctor Clark and Doctor Hanna also gave information concerning the Tertiary species from California. Mr. Ralph B. Stewart, of the University of California, read the manuscript, and I have taken advantage of his suggestions. I am also indebted to Mr. L. R. Cox, of the British Museum, for information relating to the fossil species from Persia, Zanzibar, and Burma, and to Dr. Axel A. Olsson, of the International Petroleum Co., for data concerning undescribed Tertiary species from Peru.

THE GENUS CLEMENTIA

CHARACTERISTIC FEATURES

Clementia is a clamlike bivalve mollusk of the family Veneridae, which embraces a large number of fossil and living mollusks, including the hard-shelled clam (*Venus mercenaria*) and others used for food. The most elaborately sculptured and most brilliantly colored shells of this family are found in the tropical seas. The hinge and pallial sinus of this genus are its most characteristic features, as in other genera of the Veneridae. Although these features are rarely seen on fossil specimens, *Clementia* has a characteristic sculpture consisting of *Inoceramus*-like waves—a feature that suggested the name of one of the American species. *Mactra* (*Harvella*), which may be confused with *Clementia* on the basis of sculpture, belongs to the family Mactridae and has an entirely different hinge. Even if the hinge can not be seen, *Harvella* can easily be recognized, as its shell is almost equilateral, whereas almost all species of *Clementia* are very inequilateral. *Harvella* also has a sharp-crested ridge extending from the umbo to the posterior ventral edge of the shell. This ridge may not be visible on internal molds, but the shallow furrow that lies in front of it can be seen. No species of *Clementia* has either ridge or furrow. The mactroid genera *Pteropsis* and *Labiosa* (*Raeta*), which have *Clementia*-like sculpture, can readily be distinguished by their shape and other features.

The shell of most species of *Clementia* is thin and fragile. Many fossil specimens are crushed and distorted, and generally they are preserved as internal molds to which parts of the shell may cling. The thin shell and closely interlocking hinge partly account for the scarcity of detached valves that show the hinge. Most of the fossils are internal molds of both valves in attached position.

PRESENT DISTRIBUTION

The living species of *Clementia* listed on page 26 have been described. There is no modern revision of the genus, and some of the names in the list, which is probably incomplete, may be duplicates.

The present range of the subgenera *Clementia* s. s. and *Egesta* is diagrammatically shown in Figure 1. The living species of *Clementia* s. s. are strung out in the western Pacific from Japanese waters southward to Tasmania. Species also are recorded from the Indian Ocean, the Red Sea, and South Africa. Most of these living Clementias are concentrated in the region from the Philippine Islands southward to Australia and in the Indian Ocean—that is, they are found in the tropical waters of the western Pacific and Indian Oceans and also in the cooler waters of southern Australia. Though the range of *Clementia* s. s. is probably continuous from Tasmania and Australia northward to Japan and westward along the border of the Indian Ocean, it is plotted in Figure 1 only at localities for which records could be found. There seem to be only two living species of *Egesta*, one in the waters off Japan and Chosen and the other in the Gulf of California.

Living species of Clementia

Species	Type locality
Clementia (Clementia) hyalina (Philippi) [a]	Philippine Islands (?).
Clementia (Clementia) similis Sowerby [b]	Philippine Islands.
Clementia (Clementia) granulifera Sowerby [c]	Do.
Clementia (Clementia) papyracea (Gray) [d]	Australia.
Clementia (Clementia) strangei Deshayes [e]	Do.
Clementia (Clementia) moretonensis Deshayes [f]	Do.
Clementia (Clementia) tasmanica Petterd [g]	Tasmania.
Clementia (Clementia) vitrea (Chemnitz) [h]	Indian Ocean.
Clementia (Clementia) crassiplica (Lamarck) [i]	Indian Ocean (?).
Clementia (Clementia) annandalei Preston [j]	Indian Ocean.
Clementia (Clementia) cumingii Deshayes [k]	Red Sea.
Clementia (Clementia) mcclellandi Tomlin [l]	South Africa.
Clementia (Egesta) vatheliti Mabille [m]	Japan.
Clementia (Egesta) solida Dall [n]	Gulf of California.

[a] Philippi, R. A., Abbildungen und Beschreibungen neuer oder wenig gekannten Conchylien, vol. 3, p. 83, *Venus*, pl. 10 (XXII, 5), fig. 6, 1851.
[b] Sowerby, G. B., Thesaurus Conchyliorum, pt. 13, pp. 700–701, pl. 151, fig. 156, 1852.
[c] Idem, p. 701, pl. 151, fig. 154.
[d] Gray, J. E., A list and description of some species of shells not taken notice of by Lamarck: Ann. Philosophy, new ser., vol. 9, p. 137, 1825. Wood, W., Supplement to the Index Testaceologicus, p. 5, pl. 2, fig. 8, 1828.
[e] Deshayes, G. P., Descriptions of two new species of *Clementia* in the collection of Hugh Cuming, Esq.: Zool. Soc. London Proc., pt. 21, p. 17, 1853.
[f] Idem, p. 18.
[g] Petterd, W. F., Description of new Tasmanian shells: Jour. Conchology, vol. 4, p. 145, 1884.
[h] Chemnitz, J. H., Neues systematisches Conchylien-Cabinet, vol. 11, p. 219, pl. 200, figs. 1959–1960, 1795.
[i] Lamarck, M. le Chevalier de, Histoire naturelle des animaux sans vertèbres, vol. 5, p. 471, 1818. Lamy, Édouard, Révision des Mactridae vivants du Muséum d'histoire naturelle de Paris: Jour. Conchyliologie, vol. 63, pp. 273, 363, pl. 7, fig. 8, 1917.
[j] Preston, H. B., Mollusca from the Chilka Lake on the east coast of India: Indian Mus. Rec., vol. 10, p. 306, figs. 14, 14 *a*, *b*, 1914.
[k] Deshayes, G. P., Descriptions of new shells from the collections of Hugh Cuming, Esq.: Zool. Soc. London Proc., pt. 22, p. 346, 1854.
[l] Tomlin, J. R. le B., Six new marine shells from South Africa: Jour. Conchology, vol. 16, p. 215, pl. 8, fig. 6, 1921.
[m] Mabille, Jules, Testarum novarum diagonoses: Soc. philomathique Paris Bull., 9th ser., vol. 3, pp. 57–58, 1901. Jukes-Browne, A. J., On a new species of *Clementia*: Annals and Mag. Nat. Hist., 8th ser., vol. 12, pp. 61–62, pl. 1, figs. 3–4, 1913.
[n] Dall, W. H., Synopsis of the family Veneridae and of the North American Recent species: U. S. Nat. Mus. Proc., vol. 26, pp. 401–402, pl. 14, fig. 4, 1902.

Jukes-Browne [1] described as *Clementia obliqua* a shell that was supposed to have been collected at Mayaguez, Porto Rico. Dall [2] showed that this shell not only is not a *Clementia* but must have been collected on the Pacific coast of North America, for it is the species described by Carpenter [3] in 1865 as *Clementia? subdiaphana*, now referred to the genus *Marcia*. Jukes-Browne [4] admitted the error as to locality, but still considered *Marcia subdiaphana* a species of *Clementia*.

GEOLOGIC HISTORY

The localities where Tertiary species of *Clementia* s. s. and *Egesta* have been found are shown diagrammatically in Figure 1. So far as known Tertiary species of *Egesta* are confined to the United States and Mexico. *Clementia* s. s. was more widely distributed particularly in America and the Orient. In America a suite of Eocene, Oligocene, and Miocene species has been collected at several localities extending from Brazil and Trinidad to Costa Rica along the Atlantic and Caribbean coasts, and from Peru to Costa Rica along the Pacific coast. The middle Miocene (Helvetian) marls of St. Florian (or Grosse Florian) in the Gratz Basin, province of Styria, Austria, carry the only European Tertiary species, *Clementia* (*Clementia*) *ungeri* (Rolle).[5] Furthermore, this is the only locality in Europe where this species has been found. According to Rolle's figures of the exterior and right hinge, *Clementia* (*Clementia*) *ungeri* closely resembles the small living oriental species. Fuchs [6] described as "*Venus* (*Clementia*) cf. *ungeri* Rolle" molds that were collected from middle Miocene beds cropping out in the Siwah oasis, in the Libyan Desert. In contrast to these isolated finds in Europe and north Africa, *Clementia* s. s. has been recorded at the localities in the Orient and east Africa listed on page 28. The names used in the list are those given by the writers cited, most of whom regard these Tertiary Clementias as representing living species.

[1] Jukes-Browne, A. J., On a new species of *Clementia*: Annals and Mag. Nat. Hist., 8th ser., vol. 12, pp. 58–62, pl. 1, figs. 1–2, 1913.

[2] Dall, W. H., Note on *Clementia obliqua* Jukes-Browne: Nautilus, vol. 27, pp. 103–104, 1914.

[3] Carpenter, P. P., Diagnoses specierum et varietatum novarum Moluscorum, prope Sinum Pugetianum a Kennerlio Doctore, nuper decesso, collectorum: Acad. Nat. Sci. Philadelphia Proc., vol. 17, p. 56, 1865.

[4] Jukes-Browne, A. J., Note on *Clementia subdiaphana* Carpenter: Annals and Mag. Nat. Hist., 8th ser., vol. 13, pp. 338–339, 1914.

[5] Rolle, Friedrich, Die tertiären und diluvialen Ablagerungen in der Gegend zwischen Gratz, Köflach, Schwanberg und Ehrenhausen in Steiermark: K.-k. geol. Reichsanstalt Jahrb., vol. 7, p. 572, 1856; Über einige neue oder wenig gekannte Mollusken-Arten aus Tertiär-Ablagerungen: K. Akad. Wiss. Wien Sitzungsber., Math.-Naturwiss. Classe, vol. 44, pt. 1, pp. 215–217, pl. 2, figs. 1, 1*a*, 2, 2*a*, 1862.

[6] Fuchs, Theodor, Beiträge zur Kenntnis der Miocaenfauna Aegyptens und der Libyschen Wüste, in Zittel, K. A., Beiträge zur Geologie und Palaeontologie der Libyschen Wüste und der angrenzenden Gebiete von Aegypten, pt. 2: Palaeontographica, vol. 30, pt. 1, p. 39 (p. 21), pl. 6, fig. 9, 1883.

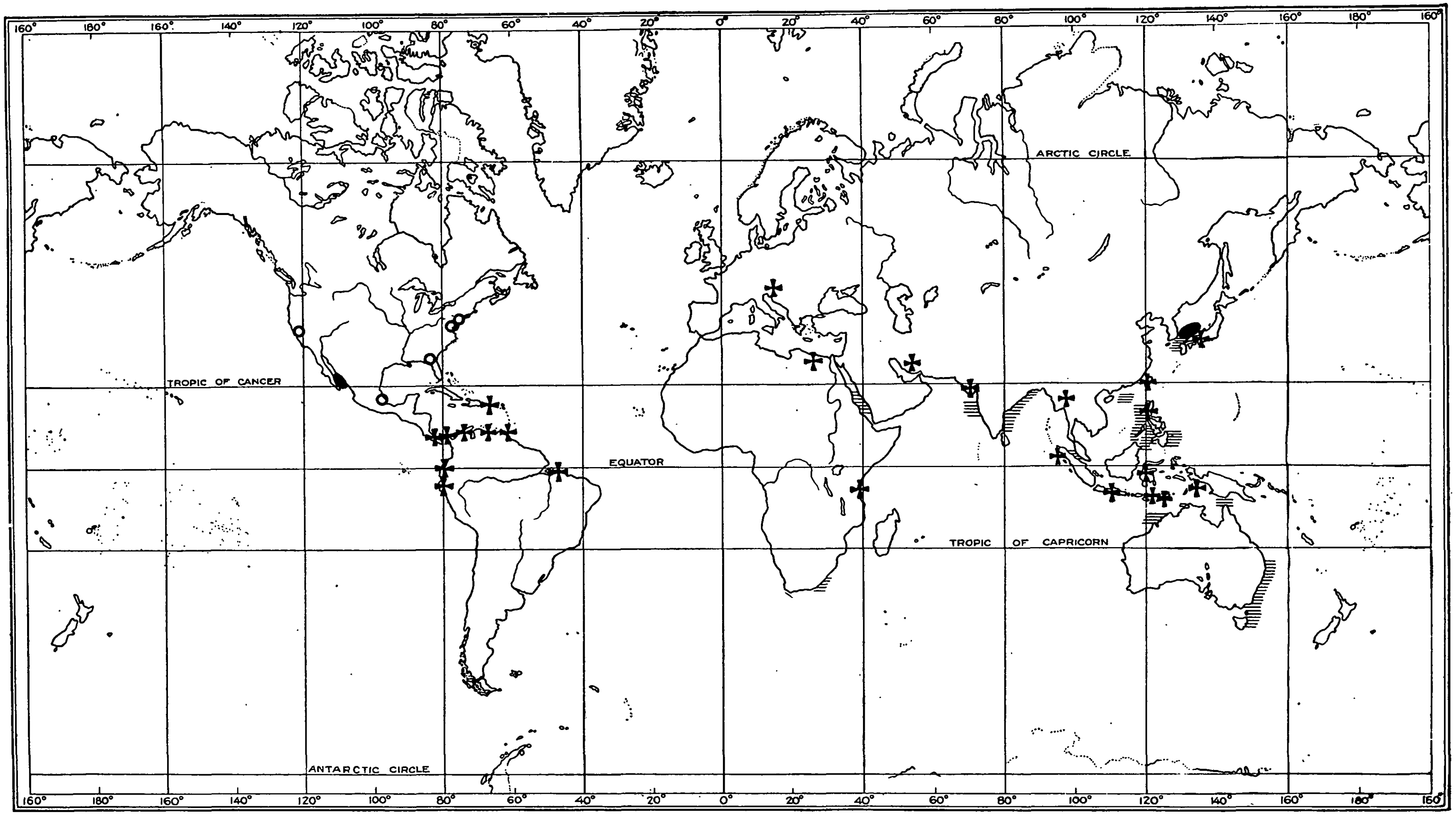


Figure 1.—Map showing present range and former distribution of *Clementia* s. s. and *Egesta*. Present range: *Clementia* s. s., lined areas; *Egesta*, solid black areas. Tertiary localities: *Clementia* s. s., crosses; *Egesta*, circles

Oriental and east African Tertiary species of Clementia s. s.

Species	Locality	Age
Clementia sp.[a]	Persia	Fars series (late Miocene or Pliocene).
Clementia nonscripta (J. de C. Sowerby).[b]	Province of Sind, western India.	Gaj group (Miocene).
Clementia hyderabadensis (d'Archiac and Haime.)[c]	do	Do.
Clementia nonscripta (J. de C. Sowerby).[d]	Burma	Miocene.
Clementia nonscripta (J. de C. Sowerby).[e]	Nias Island, off southwest coast of Sumatra.	Miocene(?).
Clementia papyracea (Gray)[f]	Java	Miocene.
Clementia papyracea (Gray)[g]	Adenara Island, east of Flores.	Late Tertiary.
Clementia papyracea (Gray)[h]	Timor	Pliocene.
Clementia nonscripta (J. de C. Sowerby)[i] [C. papyracea (Gray)][j]	Celebes	Late Tertiary.
Clementia nonscripta (J. de C. Sowerby) var.?[k]	Aru Islands, south of New Guinea.	Do.
Clementia papyracea (Gray)[l] [C. hyalina (Philippi)][m]	Luzon, P. I.	Miocene.
Clementia nonscripta (J. de C. Sowerby).[n]	Formosa	Tertiary.
Clementia speciosa Yokoyama[o]	Japan	Pliocene.
Clementia nonscripta (J. de C. Sowerby).[p]	Zanzibar, east Africa	Miocene.

[a] Pilgrim, G. E., The geology of parts of the Persian provinces of Fars, Kirman, and Laristan: India Geol. Survey Mem., vol. 48, pt. 2, p. 89, 1924. In 1908 Pilgrim listed "*Clementia* n. sp. aff. *cumingii* Desh., *Clementia* n. sp. aff. *non scripta* d'A. & H., and *Clementia* n. sp." from the Fars series (India Geol. Survey Mem., vol. 34, pt. 4, p. 46, 1908).

[b] Sowerby, J. de C., in Grant, C. W., Memoir to illustrate a geological map of Cutch: Geol. Soc. London Trans., 2d ser., vol. 5, p. 327, pl. 25, fig. 8, 1840. D'Archiac, le Vicomte, and Haime, Jules, Description des animaux fossiles du groupe Nummulitique de l'Inde, p. 246, pl. 17, figs. 7, 7*a*, Paris, 1853. Fedden, J., On the distribution of the fossils described by Messrs. D'Archiac and Haime in the different Tertiary and Infra-Tertiary groups of Sind: Geol. Survey India Mem., vol. 17, p. 202, 1880.

[c] D'Archiac, le Vicomte, and Haime, Jules, op. cit., p. 247, pl. 17, figs. 8, 8a. Fedden, J., op. cit.

[d] Cox, L. R., Some late Kainozoic Pelecypoda from the Aru Islands: Geol. Mag., vol. 61, No. 716, p. 63, 1924.

[e] Woodward, Henry, Further notes on a collection of fossil shells, etc., from Sumatra, pt. 2: Geol. Mag., decade 2, vol. 6, p. 442, pl. 11, fig. 3, 1879. Reprint, Mijnwezen in Nederlandsch Oost-Indië Jaarboek, year 9, p. 224, pl. 3, fig. 3, 1880.

[f] Martin, K., Die Tertiärschichten auf Java, pp. 99–100, pl. 17, figs. 6, 6*a*, Leiden, 1879–80; Die altmiocäne Fauna des West-Progogebirges auf Java, pt. B: Geol. Reichs-Mus. Leiden Samml., new ser., vol. 2, No. 7, p. 273, 1917.

[g] Martin, K., op. cit. (1879–80), p. 100; op. cit. (1917), p. 273.

[h] Boettger, O., Liste die tertiären und jüngeren Versteinerungen, in Verbeek, R. D. M., Geologische verkenningstochten in het oostelijke gedeelte van den Nederlandsch Oost-Indischen Archipel: Mijnwezen in Nederlandsch Oost-Indië Jaarboek, year 37, p. 669, 1908.

[i] Dollfus, G. F., Paléontologie du voyage à l'île Célèbes de M. E. C. Abendanon, in Abendanon, E. C., Geologische en geographische Doorkruisingen van Midden-Celebes, vol. 3, p. 994, pl. 1, figs. 817, 818, 818*a*, Leiden, 1917. (French ed., pp. 1012–1013, pl. 1, figs. 817, 818, 818*a*, Leiden, 1918.)

[j] Martin, K., Bemerkungen über sogenannt oligocäne und andere Versteinerungen von Celebes: Geol. Reichs-Mus. Leiden Samml., new ser., vol. 2, No. 7, p. 301, 1917. Dollfus considered these deposits of Oligocene age, but according to Martin they are Miocene or later.

[k] Cox, L. R., Some late Kainozoic Pelecypoda from the Aru Islands: Geol. Mag., vol. 61, No. 716, p. 62, fig. 4, 1924.

[l] Martin, K., Über Tertiaere Fossilien von den Philippinen: Geol. Reichs-Mus. Leiden Samml., vol. 5, pp. 57, 59, 1896. English translation, Concerning Tertiary fossils in the Philippines, in Becker, G. F., Report on the geology of the Philippine Islands: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 3, pp. 618, 619, 1901. Smith, W. D., Contributions to the stratigraphy and fossil invertebrate fauna of the Philippine Islands: Philippine Jour. Sci., vol. 8, sec. A, p. 272, pl. 7, fig. 5, pl. 8, fig. 3, 1913.

[m] Dickerson, R. E., A fauna of the Vigo group; its bearing on the evolution of marine molluscan faunas: Philippine Jour. Sci., vol. 18, p. 12, 1921. Reprint under title, Notes on a fauna of the Vigo group and its bearing on the evolution of marine molluscan faunas: California Acad. Sci. Proc., 4th ser., vol. 11, p. 15, 1921.

[n] Cox, L. R., Some late Kainozoic Pelecypoda from the Aru Islands: Geol. Mag., vol. 61, No. 716, p. 63, 1924.

[o] Yokoyama, M., Tertiary Mollusca from Deinichi in Totomi: Tokyo Imp. Univ. Coll. Sci. Jour., vol. 45, art. 2, p. 15, pl. 2, figs. 14–15, 1923 (I have not seen this report); Mollusca from the Tertiary basin of Chichibu: Tokyo Imp. Univ. Faculty Sci. Jour., sec. 2, vol. 1, pt. 3, p. 119, pl. 14, fig. 7, 1925; Molluscan fossils from the Tertiary of Mino: Idem, pt. 7, p. 222, 1926.

[p] Cox, L. R., op. cit. and written communication.

Clementia s. s. and *Egesta*, like many other groups of mollusks, had an extensive distribution in the Tertiary seas, but are now restricted to the Pacific and Indian Oceans. It is difficult to trace the history of this expansion and subsequent restriction. Characteristic species of *Clementia* s. s. appear in the deposits of the middle Eocene Caribbean Sea and also in those of the eastern Pacific, where, according to Olsson,[7] the genus is represented in the middle Eocene deposits of Peru. The ancestry of these American Clementias is unknown. Jukes-Browne[8] suggested that *Venus ovalis* Sowerby, a species from the Upper Greensand (Albian, upper part of Lower Cretaceous) of England, is an ancestral *Clementia* and proposed for it the name *Flaventia* as a subgenus of *Clementia*. This species is so different from the American Eocene Clementias that there is no reason to believe it is an ancestral *Clementia*. Its sculpture is different; its lunule is bounded by a groove; its right posterior cardinal consists of two distinct parts of unequal length; according to Woods's figures,[9] its left anterior cardinal is bifid; and its pallial sinus is not so deep. *Clementia deshayesi*, an Eocene species from the Paris Basin described by Cossmann[10] more closely resembles *Clementia*, as it has a thin shell and concentric waves, and at least the right valve has a *Clementia*-like hinge. But its truncate posterior end, well-defined escutcheon, and lunule bordered by a groove show that it is not like the living species of *Clementia* s. s. or like the American Tertiary species. It probably represents a divergence from an unknown ancestral stock, similar to the later divergence of *Egesta* in American waters.

The American *Clementia* (*Clementia*) *dariena vetula*, *C.* (*C.*) *dariena rabelli*, and *C.* (*C.*) *dariena dariena* seem to represent a continuous genetic stock developed in American seas. One of the routes by which *Clementia* s. s. migrated from the eastern Pacific into the Caribbean Sea, or in the opposite direction, is indicated by the discovery of *C.* (*C.*) *dariena dariena* in beds cropping out at Santa Maria de Dota, in central Costa Rica near the east edge of the province of San Jose. This subspecies has also been collected on the Pacific coast of Costa Rica near Punta Arenas and on the Atlantic side of Costa Rica in the valley of Rio Revantazon. The deposits extending across Costa Rica, which seem to be of lower Miocene age, were laid down in a channel that connected the Pacific Ocean and Caribbean Sea, as several writers have pointed out.[11] At most places these beds are concealed by later lava and tuff, but they crop out at several localities.

If it is assumed that the American Tertiary species belong to the same genetic stock as the living oriental species, *Clementia* s. s. probably migrated from the eastern Pacific to the oriental region by way of the north border of the Pacific, perhaps during Eocene time, when climatic zones were not so marked as now.

[7] Olsson, A. A., written communication.

[8] Jukes-Browne, A. J., On the genera of Veneridae represented in the Cretaceous and older Tertiary deposits: Malacol. Soc. London Proc., vol. 8, pp. 167–169, pl. 6, fig. 10, 1909.

[9] Woods, Henry, A monograph of the Cretaceous Lamellibranchia of England, vol. 2, pt. 5, pp. 191–192, pl. 29, figs. 19–26, Palaeontographical Soc., 1908.

[10] Cossmann, M., Catalogue des coquilles fossiles de l'Eocène des environs de Paris: Soc. roy. malacol. Belgique Annales, vol. 21 (4th ser., vol. 1), pp. 127–128, pl. 7, figs. 1–2, 1886.

[11] Gabb, W. M., On the geology of the Republic of Costa Rica (manuscript in library of U. S. Geological Survey), pp. 45–46. Alfaro, Anastasio, Comprobaciones geológicas: Bol. de Fomento, year 1, pp. 123–124, 1911. Romanes, James, Geology of a part of Costa Rica: Geol. Soc. London Quart. Jour., vol. 68, p. 137, 1912. Olsson, A. A., The Miocene of northern Costa Rica: Bull. Am. Paleontology, vol. 9, pp. 205–206, 1922.

This supposition is not confirmed by fossil occurrences, for no Tertiary species are known in the north Pacific, and in the Orient the earliest species that are definitely dated are of Miocene age. For some unknown reason after Miocene time this subgenus disappeared in the Caribbean Sea and in the eastern Pacific.

Clementia (*Clementia*) *ungeri*, which is recorded from Miocene beds in Egypt and Austria, probably represents a temporary Miocene invasion of oriental mollusks into the Mediterranean Sea. This invasion is attested by other genera, such as *Cancellaria* (*Scalptia*), *Cancellaria* (*Ventrilia*), *Mitra* (*Thala*), *Stossichia*, group of *Turritella terebralis*,[12] and *Placuna*. Dr. A. Morley Davies, of the Imperial College of Science and Technology, who has recently discussed some of the evidence for this invasion,[13] kindly called attention to these oriental genera that are found in Mediterranean Miocene deposits but not in earlier deposits in the Mediterranean region. There is a possibility that some of these genera represent a migration in the opposite direction, but it is more probable that they are autochthonous in oriental seas.

Egesta apparently represents a divergence from the American stock of Clementias. It first appeared in the Gulf of Mexico in Miocene time and in California apparently at almost the same time. Its route of migration across America is not known. It has not been found in the Caribbean region, and apparently the route lay farther north, perhaps in the Isthmus of Tehuantepec. During late Miocene time it migrated out of the Gulf of Mexico as far north as the Chesapeake embayment and New Jersey. For some unknown reason it then disappeared in Atlantic waters, but it remained in the eastern Pacific, where it is now found in the Gulf of California. Inasmuch as an *Egesta* that is similar to the fossils of the southeastern United States is now found in Japanese waters, it is assumed to represent a migration around the north border of the Pacific during late Tertiary time, though again no fossil records substantitate this supposition. This group of Egestas is unrepresented in the Tertiary deposits of California, and it is also not represented at the present time in the eastern Pacific. A second phylum of *Egesta*, typified by *Clementia* (*Egesta*) *pertenuis*, is found only as Miocene and Pliocene fossils in California. A third phylum seems to be represented by *C.* (*E.*) *conradiana*, a Miocene species from California, and *C.* (*E.*) *solida*, now living in the Gulf of California.

PALEOBIOLOGIC SIGNIFICANCE

There seem to be no records of the conditions under which *Egesta* lives. Dredging records of *Clementia* s. s. that could be gathered from published accounts are as follows:

Dredging records of Clementia s. s.

Species	Locality	Depth (fathoms)	Character of bottom
Clementia (Clementia) granulifera Sowerby. [a]	Manila Bay, Philippine Islands.	4-6	Sandy mud.
Clementia (Clementia) papyracea (Gray). [b]	Torres Strait, south of New Guinea.	3-11	
Clementia (Clementia) tasmanica Petterd. [c]	Off Long Bay and Brown's River, Tasmania.	7	
Clementia (Clementia) annandalei Preston. [d]	Lake Chilka and other localities, India.	1-2	Mud.

[a] Sowerby, G. B., Thesaurus conchyliorum, pt. 13, p. 701, 1852.
[b] Smith, E. A., Report on the Lamellibranchiata: *Challenger* Rept., Zoology, vol 13, pt. 35, p. 154, 1885.
[c] Petterd, W. F., Description of new Tasmanian shells: Jour. Conchology, vol. 4, p. 145, 1884.
[d] Preston, H. B., Mollusca from the Chilka Lake on the east coast of India: Indian Mus. Rec., vol. 10, p. 306, 1914. (Lake Chilka is a lagoon of salt water connected with the sea.)

Through the kindness of Dr. Paul Bartsch, curator of the division of mollusks of the United States National Museum, the following records are given of unstudied specimens of *Clementia* s. s. collected by the United States Bureau of Fisheries steamer *Albatross* in the seas adjoining the Philippine Islands.

Dredging records of Clementia s. s. collected by U. S. Bureau of Fisheries steamer Albatross in Philippine waters

Station	Locality	Number of specimens	Depth (fathoms)	Character of bottom
5164	Off Tawi Tawi Island, Sulu Archipelago.	1 right valve	18	Green mud.
5593	Sibuko Bay, Borneo	1 right valve	38	Fine sand.
5358	Off Sandakan Light, Borneo	3 right valves, 1 left valve.	39	Mud.
5235	Nagubat Island, east coast of Mindanao, Philippine Islands.	1 right, 1 left valve.	44	Soft mud.
5311	China Sea, off Pratas Island	1 left valve	88	Coarse sand and shells.

None of these records show whether living or dead shells were collected. Probably all the shells were dead, but it is not likely that these paper-thin shells were carried far by waves or currents. According to these records *Clementia* s. s. lives in protected shallow water at depths of 1 to 11 fathoms, or in quiet deeper water in exposed localities at depths of 18 to 88 fathoms. In both the shallow and the deeper water it is generally found on a bottom of mud or fine sand. This habitat is in harmony with the thin texture of the shell. No observations have been made on living shells, but the deep pallial sinus and the statement by Deshayes[14] to the effect that *Clementia* s. s. has long united siphons show that it burrows in the mud or fine sand.

Clementia s. s. lives in sea water of normal salinity and also in water of low salinity. According to Stoliczka,[15] two unnamed species were collected in brackish water

[12] Guillaume, L., Essai sur la classification des Turritelles, ainsi que sur leur évolution et leurs migrations, depuis la début des temps tertiaires: Soc. géol. France Bull., 4th ser., vol. 24, pp. 300-302, 1924.
[13] Wayland, E. J., and Davies, A. M., The Miocene of Ceylon: Geol. Soc. London Quart. Jour., vol. 79, pp. 588-589, 591, 1923.

[14] Deshayes, G. P., Catalogue of the Conchifera or bivalve shells in the collection of the British Museum, pt. 1, p. 197, 1853. This statement seems to be the basis for the accounts in the manuals.
[15] Stoliczka, F., Cretaceous fauna of southern India, vol. 3, Pelecypoda. Geol. Survey India Mem., Palaeontographica Indica, 6th ser., pts. 1-4, p. 158, 1871.

near Calcutta, and Preston[16] recorded *C.* (*C.*) *annandalei* from Port Canning, in the Gangetic delta.

No field studies have been made with the object of gathering data on the manner in which the American fossil species of *Clementia* s. s. lived and died, but their occurrence confirms the assumption that they lived under essentially the same conditions as the present living species, with the exception that there is no evidence to show that the fossil species tolerated water of low salinity. In the whole Caribbean region *Clementia* is found in beds of mud, which may be calcareous, and in fine sand, but not in coarse sand or gravel nor in reef limestones. This bottom control explains its absence in many parts of the Carribbean region. The Eocene beds in Colombia carrying *Clementia* are mud deposits, but no specimens have been collected from widespread Eocene reef limestones of the Caribbean region. In Porto Rico *Clementia* is found in the mud beds at the base of the Tertiary deposits, which are of middle Oligocene age, and not in the overlying limestones. Elsewhere in the Caribbean region deposits of middle Oligocene age are reef limestones, in which *Clementia* has never been found. The mud beds in the Gatun formation of the Panama Canal Zone carry more specimens than any other Tertiary deposit in the Caribbean region. Along the Caribbean coast of Costa Rica *Clementia* is not found in the coralliferous limestones of the Gatun formation nor in the strand sandstones or conglomerates, nor in the coastal-swamp muds, but only in the mud or fine sand that was deposited between the reefs and the strand. Bottom control excludes *Clementia* from the middle Miocene Bowden formation of Jamaica, which carries a fauna of species that lived on a gravelly or sandy bottom at depths ranging from the intertidal zone to about 200 fathoms. In Venezuela and Brazil specimens are found in limestones or in less calcareous mud beds. It is strange that no Clementias have been discovered in the Miocene mud deposits of the Dominican Republic and the Republic of Haiti, although hundreds of species of mollusks and thousands of shells have been collected from these beds. They carry many large, heavy shells, and the water in which they were deposited may have been too much agitated. This explanation is not entirely satisfactory, for it is unreasonable to believe that the water was nowhere in this area quiet enough to permit these mollusks to live.

These burrowing shells apparently lived and died and were buried at or close to the place where they now are found—that is, their occurrence is autochton, to use the nomenclature introduced by Ehrenberg.[17] They are almost invariably found with both valves in attached position, indicating that they remained buried in the mud or fine sand in which they burrowed while they were alive. If they had lain unburied for some time on the sea bottom the valves would now gape or would be separated, depending on whether they were buried before or after the ligament decayed. If these thin shells had been washed about they would soon have been broken up. Unfortunately there are no confirmatory data with regard to the orientation of the shells in the deposits from which they have been collected.

The heavier shells of *Egesta* are in harmony with their occurrence in sands and sandstones, though they are also found in marls. Some of the sandstones in California that carry *Egesta* are coarse, but generally specimens are not found in pebbly sandstones or conglomerates. These mollusks burrowed in sand or mud. Their shells may at times have been carried by waves and currents some distance from the place where they lived and died, for detached valves are found at some localities.

The distribution of these two subgenera—*Clementia* and *Egesta*—also affords evidence of temperature control. Figure 1 shows that the American Tertiary species of *Clementia* s. s. were confined to tropical seas. On the Atlantic side the genus never got farther north than the Caribbean Sea. On the Pacific side fossil species have been found in northern Peru, Ecuador, Panama, and Costa Rica. The occurrence of *Clementia* s. s. in the Tertiary seas of the Orient is in harmony with its distribution in American Tertiary seas, and the Miocene Mediterranean Sea, in which the deposits of the Gratz Basin and Libyan Desert were laid down, was warmer than the present Mediterranean Sea. At the present time this subgenus is found in both tropical and warm temperate seas. In the waters of the Miocene Gulf of Mexico and on the Atlantic and Pacific coasts of the United States *Clementia* s. s. was replaced by *Egesta*. According to present interpretations, *Egesta* tolerated a considerable temperature range, for it is found in a variety of faunas ranging from the subtropical fauna of the Chipola formation of Florida to the warm-temperate faunas of the Calvert and Choptank formations of Maryland but not in cool temperate or boreal faunas. At the present time *Egesta* is found in the Gulf of California but not in the cooler waters of the California coast. Temperature control may account for its absence in the Pliocene deposits of California except in the warm-water facies of the Purisima formation.

AMERICAN TERTIARY SPECIES

The American Tertiary species of *Clementia* s. s. and *Egesta*, their age, and the localities where they have been found are as follows:

[16] Preston, H. B., Mollusca from the Chilka Lake, on the east coast of India: Indian Mus. Rec., vol. 10, p. 306, 1914.

[17] Ehrenberg, Kurt, Über das Vorkommen von Fossilresten: Naturwissenschaften, year 12, No. 29, pp. 593-596, 1924.

Clementia (*Clementia*) *dariena vetula* Woodring, n. subsp., middle Eocene, Colombia.
Clementia (*Clementia*) *dariena rabelli* Maury, middle Oligocene, Porto Rico.
Clementia (*Clementia*) *dariena dariena* (Conrad), lower and middle Miocene, Panama (Atlantic and Pacific sides), Costa Rica (Atlantic and Pacific sides and interior), Colombia, Venezuela, Trinidad, Brazil, Ecuador, and Peru.
Clementia (*Egesta*) *grayi* Dall, lower and middle Miocene, Florida, and lower Miocene, Mexico.
Clementia (*Egesta*) *inoceriformis* (Wagner), middle Miocene, Maryland, and upper Miocene, New Jersey.
Clementia (*Egesta*) *conradiana* (F. M. Anderson), lower and middle Miocene, California.
Clementia (*Egesta*) *martini* (Clark), upper Miocene, California.
Clementia (*Egesta*) *pertenuis* (Gabb), lower Miocene to lower Pliocene, California.

The following table shows at a glance the comparative age of these species:

Age and distribution of American Tertiary species of Clementia

Time divisions		Atlantic coast of United States	Borders of Gulf of Mexico	Caribbean region	Pacific coast of Central America and northern South America	Pacific coast of United States
Pliocene	Upper					
	Middle					
	Lower					*Clementia* (*Egesta*) *pertenuis*, Purisima formation, California.
Miocene	Upper	*Clementia* (*Egesta*) *inoceriformis*, Kirkwood formation (Shiloh marl member), New Jersey.				*Clementia* (*Egesta*) *martini*, San Pablo formation (upper part) and Santa Margarita formation, California. *Clementia* (*Egesta*) *pertenuis*, *C.* (*E.*) *conradiana*, Santa Margarita formation, California.
	Middle	*Clementia* (*Egesta*) *inoceriformis*, Calvert, Choptank, and St. Marys formations, Maryland.	*Clementia* (*Egesta*) *grayi*, Shoal River formation, Florida.	*Clementia* (*Clementia*) *dariena dariena*, Gatun formation, Panama; Costa Rica; Colombia.	*Clementia* (*Clementia*) *dariena dariena*, Zorritos formation, Peru; Panama.	*Clementia* (*Egesta*) *pertenuis*, Topanga formation and *Turritella ocoyana* zone, California. *Clementia* (*Egesta*) *conradiana*, *Turritella ocoyana* zone, California.
	Lower		*Clementia* (*Egesta*) *grayi*, Chipola and Oak Grove formations, Florida; Tuxpan formation, Mexico.	*Clementia* (*Clementia*) *dariena dariena*, Culebra formation (upper part), Panama; Costa Rica; Colombia; Venezuela; Trinidad; Brazil.	*Clementia* (*Clementia*) *dariena dariena*, Ecuador; Panama; Costa Rica.	*Clementia* (*Egesta*) *pertenuis*, *C.* (*E.*) *conradiana*, Vaqueros formation (*Turritella inezana* zone), California.
Oligocene	Upper				*Clementia* (*Clementia*) sp. b, Peru.	
	Middle			*Clementia* (*Clementia*) *dariena rabelli*, San Sebastian shale and Juana Diaz shale, Porto Rico.		
	Lower					
Eocene	Upper				*Clementia* (*Clementia*) sp. b, Peru.	
	Middle			*Clementia* (*Clementia*) *dariena vetula*, Colombia.	*Clementia* (*Clementia*) sp. b, Peru. *Clementia* (*Clementia*) sp. a, Peru.	
	Lower					

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Clementia? taeniosa Guppy,[18] an upper Miocene species from Trinidad, is a *Mactra* (*Harvella*). The type of this species is in the collections of the United States National Museum (catalog No. 107106). It may possibly be the species recently named *Mactra* (*Harvella*) *sancti-blasi* by Maury,[19] though it is larger than Maury's type and has fuller umbos. *Dosinia mercenaroides* Aldrich, a species from the middle Eocene Gosport sand of Alabama, described by Harris[20] as a *Clementia*, has none of the features of *Clementia* s. s. or *Egesta*. The discovery of characteristic Eocene Clementias in Colombia and Peru disposes of the idea, advocated by Harris, that this species is a transitional form leading up to *Clementia*.

Key to the American Tertiary species of Clementia

Shell thin, upper posterior slope not concave, posterior end not truncate, pallial sinus relatively wide. Subgenus *Clementia* s. s.
- Anterior end extended, length of adult shell not exceeding 45 millimeters ______ *C.* (*C.*) *dariena vetula.*
- Anterior end not extended:
  - Length of adult shell not exceeding 50 millimeters *C.* (*C.*) *dariena rabelli.*
  - Length of adult shell not exceeding 80 millimeters *C.* (*C.*) *dariena dariena.*

Shell thin or relatively thick, upper posterior slope generally concave, posterior end generally truncate, pallial sinus very narrow ______ Subgenus *Egesta.*
- Upper posterior slope concave, posterior end truncate:
  - Shell very inequilateral ______ *C.* (*E.*) *grayi.*
  - Shell moderately inequilateral ______ *C.* (*E.*) *inoceriformis.*
- Upper posterior slope not concave, posterior end not truncate:
  - Lunular area deeply depressed ______ *C.* (*E.*) *conradiana.*
  - Lunular area not deeply depressed:
    - Shell moderately inequilateral ______ *C.* (*E.*) *martini.*
    - Shell slightly inequilateral ______ *C.* (*E.*) *pertenuis.*

DESCRIPTION OF SPECIES

Family VENERIDAE

Subfamily DOSINIINAE

Genus CLEMENTIA Gray

Subgenus CLEMENTIA s. s.

Gray, Synopsis of the contents of the British Museum, ed. 44, p. 75, 1842 (genus without species); Zool. Soc. London Proc., pt. 15, p. 184, 1847.

Type (by original designation, 1847): *Venus papyracea* Gray, Ann. Philosophy, new ser., vol. 9, p. 137, 1825. Wood, Supplement to the Index Testaceologicus, p. 5, pl. 2, fig. 8, 1828. Recent, Australia.

Shell generally small, thin and fragile, ovate, inequilateral. Lunule recognizable only by absence or suppression of sculpture. Sculpture consisting of coarse concentric waves and fine concentric threads, both of which are strongest in the umbonal region and may be replaced on the ventral part of the shell by growth lines. Under the umbo and extending a short distance parallel to the posterior cardinal lies a narrow shallow resilium groove. Hinge of right valve consisting of an anterior cardinal, a slightly heavier middle cardinal, and a long slender bifid posterior cardinal; hinge of left valve consisting of an anterior cardinal, a long, heavy middle cardinal, and a long, very slender posterior cardinal. On both valves a deep niche, formed by the hinge plate and the margin of the shell, lies in front of the anterior cardinal. Pallial sinus deep, ascending, wide, tapering to an asymmetrically U-shaped apex.

The name *Clementia* was first used by Gray in 1840 in the forty-second edition of a booklet entitled "Synopsis of the contents of the British Museum." As no copies of any editions of this booklet are available, the following account is based on Iredale's quotations.[20a] This name as used in 1840 is absolutely nude [20b] and therefore has no standing. But in the forty-fourth edition, issued in 1842, the following is added to the name *Clementia:* "The *Tapes* and *Venerupes* have oblong shells with very compressed teeth, and the *Clementia* are like the latter but are very thin and have a cavity in the margin before and behind the teeth." [20c] On account of this brief sentence the name *Clementia* as used in 1842 must be accepted as recognizable, or it must be considered a doubtful name (nomen dubium). The statement that the shell is thin and that it has a "cavity" lying in front of and behind the hinge justifies the contention, here advocated, that the genus is recognizable on the basis of the 1842 publication, though no species are mentioned. It is assumed that the "cavity behind the teeth" refers to the space between the hinge plate and the nymph, though this "cavity" is not so pronounced as the "cavity" in front of the hinge, which is a striking feature. *Venus papyracea* still remains the genotype by original designation, for a species was first assigned to the genus in the article in the Proceedings of the Zoological Society of London, 1847, and in this article Gray definitely states that he is designating types. If the name *Clementia* as used in 1842 is considered a doubtful name, its use in 1847 is automatically invalidated. On the assumption that *Venus papyracea* and *Venus inoceriformis*, the type of *Egesta*, are congeneric, all *Clementia*-like mollusks would then take the generic name *Egesta*—a name that was published in 1845 and that everyone has overlooked—and the species similar to *Venus papyracea* would take some other name, which apparently would have to be a new name, as a subgenus of *Egesta*. The burden of proof rests on anyone who would advocate such a change in currrent nomenclature.

The very thin fragile shell, slender hinge, and wide pallial sinus are characteristic of *Clementia* s. s. The

[18] Guppy, R. J. L., U. S. Nat. Mus. Proc., vol. 19, p. 327, pl. 30, fig. 8, 1896. Dall, W. H., Wagner Free Inst. Sci. Trans., vol. 3, pt. 6, p. 1235, 1903. Maury, C. J. Bull. Am. Paleontology, vol. 10, p. 295, 1925.

[19] Maury, C. J., Bull. Am. Paleontology, vol. 10, pp. 266-267, pl. 32, fig. 2, 1925.

[20] Harris, G. D., Bull. Am. Paleontology, vol. 6, p. 151, pl. 47, figs. 8-11, 1919.

[20a] Iredale, Tom, A collation of the molluscan parts of the synopses of the contents of the British Museum, 1838-1845: Malacol. Soc. London Proc., vol. 10, pp. 294-309, 1913.

[20b] Idem, p. 298.

[20c] Idem, p. 304.

hinge plate is narrow and the hinge is spread out, so that the left middle cardinal is almost parallel to the edge of the nymph.

There are slight differences between the American species here described and the living species from the western Pacific, including the genotype, *C. papyracea;* and refined work may eventually eliminate the American species from *Clementia* s. s. The American fossils are larger than *C. papyracea* and other living species from the western Pacific, and they have a slightly heavier shell. Size alone may have no significance. *C. mcclellandi* Tomlin, a living species from South Africa, is fully as large as the American fossil *C. dariena.* All the American fossils have a recognizable escutcheon limited by a low ridge extending from the umbo almost or quite to the edge of the shell, whereas on *C. papyracea* the ridge disappears almost under the umbo. The resilium groove of the American species is wider, probably on account of the heavier shell. Though the hinge of none of the American fossils is fully known, enough of it is known to show that it is heavier than in *C. papyracea,* probably too heavy to be compensated alone by their heavier shell. Moreover, the hinge of the American fossils is compressed into a shorter space. Their pallial sinus is not quite so wide as in *C. papyracea.* On the basis of a comparison with *C. papyracea* the separation of the American fossils as a section of *Clementia* s. s. is justifiable, but such action must await a study of all the living and fossil species, for which material is not now available.

EOCENE SPECIES

Clementia (Clementia) dariena vetula Woodring, n. subsp.

Plate 14, Figures 1–4

Shell relatively small, moderately inequilateral, anterior end extended. Lunular area shallow, sculptured only with growth lines. Escutcheon narrow, limited by a ridge extending from the umbo almost or quite to the margin of the shell. Sculpture consisting of coarse concentric waves and fine low concentric threads of irregular width. Interior inaccessible except a broken right hinge, which shows a heavy middle cardinal and a long slender deeply bifid posterior cardinal.

Holotype, young shell: Length 24 millimeters, height 22 millimeters, diameter (both valves) 12 millimeters. Paratype: Length 33 millimeters, estimated height 28 millimeters, diameter (both valves) 19.8 millimeters. Another paratype: Estimated length 42 millimeters, height 32.5 millimeters, diameter (right valve) 10 millimeters.

The holotype has a definitely limited lunule, which seems to be due to a calcareous crust that at one place extends across the boundary of the lunular area. Neither paratype has a definite lunule. The ridge bounding the escutcheon is prominent. The paratype that shows the broken hinge also shows the deep, narrow groove at the upper edge of the ligament area and the long resilium groove lying back of the tip of the umbo parallel to the posterior cardinal.

This Eocene subspecies is represented by three specimens. Only one young shell, which is taken as the holotype, is perfect. It is remarkably similar to small specimens of the Miocene *C. dariena dariena.* The holotype and one of the paratypes show that the shell is more equilateral than in most specimens of *dariena dariena* (compare figs. 4 and 7, pl. 14), but some specimens of *dariena dariena* are almost as equilateral as *vetula.* The concentric waves extend to the base of the largest specimen of *vetula,* whereas on adult shells of *dariena dariena* they disappear on the lower third or less of the shell. This distinction may have no significance, as the largest shell of *vetula,* which is only half as large as the largest specimen of *dariena dariena,* may not be full grown. The difference in shape and apparent difference in size are the most significant distinctions, but they seem to be of only subspecific value.

The beds carrying *vetula* are undoubtedly of Eocene age and probably middle Eocene, although they may be as young as upper Eocene. The same collection contains a *Volutospina* very similar to *V. petrosa tuomeyi* (Conrad), from the Wilcox group of Alabama, and also similar to heavily callused specimens of *V. peruviana* Woods,[21] from the middle Eocene Parinas sandstone of Peru; a *Clavilithes* resembling *C. pacificus* Woods,[22] an Eocene species from Peru; an *Operculina* resembling *O. willcoxi* (Heilprin), an upper Eocene species from Florida; and species of *Oliva, Neverita, Lunatia, Glycymeris, "Scapharca," Callocardia,* and *Pitar* similar to species from the Claiborne group of the Gulf States. In addition to these fossils the collection contains remarkably large cashew nuts described by Berry [23] as *Anacardium eocenicum.* The possibility of mixing an Oligocene or Miocene *Clementia* with these Eocene fossils is eliminated, for the specimens of *Clementia* have precisely the same appearance as the Eocene shells and contain the same matrix, and no Oligocene or Miocene beds crop out in the region where they were collected.

Type locality: Middle Eocene, station 160 on traverse from Arroyo Macamajon to Ovejas, southeast of Pijaguay, Department of Bolivar, Colombia, R. L. Beckelhymer, collector; station 1/968; three specimens (holotype and two paratypes), all of which are figured.

Type material: Holotype (young shell, both valves in attached position), U. S. Nat. Mus. catalog No. 354036; two paratypes, U. S. Nat. Mus. catalog No. 354037.

[21] Woods, Henry, in Bosworth, T. O., and others, Geology of the Tertiary and Quaternary periods in the northwest part of Peru, pp. 101–104, pl. 15, figs. 3–5, London, 1922.

[22] Idem, pp. 99–100, pl. 13, fig. 10; pl. 14, figs. 1–2.

[23] Berry, E. W., New Tertic species of *Anacardium* and *Vantanea* from Colombia: Pan-Am. Geologist, vol. 42, pp. 259–262, pl. 18, 1924.

OLIGOCENE SPECIES

Clementia (Clementia) dariena rabelli Maury

Plate 14, Figure 5

Clementia rabelli Maury, New York Acad. Sci. Scientific Survey Porto Rico and Virgin Islands, vol. 3, pt. 1, pp. 37–38, pl. 6, figs. 2–3, 1920.

Maury, Bull. Am. Paleontology, vol. 10, p. 294, pl. 37, fig. 2, 1925.

Clementia dariena [not Conrad] Hubbard, New York Acad. Sci. Scientific Survey Porto Rico and Virgin Islands, vol. 3, pt. 2, pp. 118–120, pl. 19, figs. 10–11, 1921.

Shell medium sized, very inequilateral. Escutcheon narrow, limited by a low ridge extending from the umbo almost to the margin of the shell. Sculpture consisting of coarse concentric waves and fine concentric threads, which may not be visible on internal molds. Near the base of adult shells the concentric waves disappear and are replaced by growth lines. Hinge and pallial sinus not known.

Holotype: Length 43 millimeters, height 38 millimeters, diameter (left valve) 6 millimeters. Paratype, distorted specimen: Length 43 millimeters, height 36 millimeters, diameter (both valves) 24.5 millimeters.

Clementia dariena rabelli is even more similar to *C. dariena dariena* than *C. dariena vetula*, but it is smaller than *dariena dariena*, though a little larger than *vetula*. According to Hubbard, who tabulated the dimensions of a number of specimens of *rabelli* and *dariena dariena*, average full-grown shells of *rabelli* are about two-thirds as large as full-grown specimens of *dariena dariena*. The holotype of *rabelli* is less elongate and less inflated than specimens of *dariena dariena* of the same size, but the shape of both species is variable. According to Maury (1925), *rabelli* is more inequilateral than *dariena dariena*, but most specimens of *dariena dariena* are very inequilateral.

Clementia dariena rabelli is the only *Clementia* so far discovered in the West Indies proper and also is the only known American Oligocene *Clementia*. It is found in the middle Oligocene San Sebastian shale (also called Rio Collazo shale), at the base of the Tertiary system in northwestern Porto Rico, and in beds of the same age, known as the Juana Diaz shale, on the south side of the island.

All the American Tertiary species of *Clementia* s. s. and most of the living species have essentially the same sculpture. This feature should be borne in mind in considering the remarkable similarity of *C. dariena vetula* (middle Eocene), *C. dariena rabelli* (middle Oligocene), and *C. dariena dariena* (lower and middle Miocene). So far as shape and sculpture are concerned, these three subspecies represent a genetic stock or gens, as clearly as phylogeny can be demonstrated by the morphology of fossils. The increase in size of progressively younger specimens is the most striking feature of this series. If specimens were available from deposits of intermediate age it would be very difficult, if not impossible, to represent the different stages of this series by the usual methods of Linnean nomenclature. Inasmuch as the principal difference between *rabelli* and *dariena* is one of size, it seems desirable to consider *rabelli* a subspecies of *dariena*.

Type locality: Middle Oligocene (San Sebastian shale), Rio Collazo near San Sebastian, Porto Rico.

Other localities: Middle Oligocene (San Sebastian shale), other localities on Rio Collazo near San Sebastian, Porto Rico (Maury, Hubbard). Middle Oligocene (Juana Diaz shale), Juana Diaz, Porto Rico (Hubbard).

Type material: Holotype (left valve), Am. Mus. Nat. Hist., Div. Geology and Invertebrate Paleontology, catalog No. 22509. Paratype (distorted specimen, both valves in attached position), Am. Mus. Nat. Hist., Div. Geology and Invertebrate Paleontology, catalog No. 22508.

MIOCENE SPECIES

Clementia (Clementia) dariena dariena (Conrad)

Plate 14, Figures 6–11

Meretrix dariena Conrad, U. S. Pacific R. R. Expl., vol. 5 (33 Cong. 2d sess., H. Ex. Doc. 91), pt. 2, appendix, p. 328, pl. 6, fig. 55, 1855. (Reprint, Dall, U. S. Geol. Survey Prof. Paper 59, p. 170, 1909.)

Clementia dariena (Conrad). Gabb, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 8, p. 344, pl. 44, figs. 16, 16*a*, 1881.

Dall, Wagner Free Inst. Sci. Trans., vol. 3, pt. 6, p. 1235, 1903.

Toula, K.-k. geol. Reichsanstalt Jahrb., vol. 58, pp. 725–726, 757, pl. 27, figs. 9–10, 1909.

Brown and Pilsbry, Acad. Nat. Sci. Philadelphia Proc., vol. 63, p. 371, pl. 28, fig. 1, 1911.

Olsson, Bull. Am. Paleontology, vol. 9, pp. 404–405, pl. 34, fig. 4, 1922.

Spieker, Johns Hopkins Univ. Studies in Geology, No. 3, pp. 141–143, pl. 8, fig. 5, 1922.

Maury, Bull. Am. Paleontology, vol. 10, pp. 293–294, pl. 37, figs. 1, 3, 5–7, 1925.

Harris, in Waring, Johns Hopkins Univ., Studies in Geology, No. 7, p. 110, pl. 20, fig. 8, 1926.

Not *Cytherea? (Meretrix) dariena?* Conrad, U. S. Pacific R. R. Expl., vol. 6 (33d Cong., 2d sess., S. Ex. Doc. 78), pt. 2, p. 72, pl. 5, fig. 21, 1856 [probably = *Macrocallista maculata* (Linné)]. (Reprint, Dall, U. S. Geol. Survey Prof. Paper 59, p. 178, 1909.)

Harvella? sp. undet., Nelson, Connecticut Acad. Arts Sci. Trans., vol. 2, p. 201, 1870.

Clementia dariena [part] (Conrad) Hubbard, New York Acad. Sci. Scientific Survey Porto Rico and Virgin Islands, vol. 3, pt. 2, pp. 118–120, pl. 19, fig. 12 (not pl. 19, figs. 10–11 = *Clementia dariena rabelli* Maury), 1921.

Clementia sp. cf. *C. dariena* (Conrad). Woods, in Bosworth and others, Geology of the Tertiary and Quaternary periods in the northwest part of Peru, p. 113, pl. 20, figs. 4*a*, 4*b*, London, 1922.

?*Clementia brasiliana* Maury, Brasil Servicio geol. mineral. Mon., vol. 4, pp. 422–423, pl. 24, fig. 3, 1925.

Shell moderately large, very inequilateral. Lunular area moderately depressed. Escutcheon narrow, limited by a low ridge extending from the umbo almost to the margin of the shell. Sculpture consisting of coarse concentric waves and fine concentric threads. On the ventral third or less of adult shells the concentric waves disappear and the threads merge into growth lines. Pallial sinus deep, moderately wide, ascending.

Neotype: Length 61 millimeters, height 48.6 millimeters, diameter (both valves) 30.2 millimeters. Topotype: Length 78 millimeters, height 65 millimeters, diameter (both valves) 27 millimeters.

Most specimens of this subspecies are elongate and very inequilateral, for the umbo lies close to the anterior end. Some shells have a more extended anterior end. These less inequilateral shells, which are most abundant in lower Miocene deposits, resemble *vetula*. Two small inequilateral shells are figured for comparison with *vetula*. Most of the specimens of *C. dariena dariena* in the collections of the United States National Museum are wholly or in part internal molds, and none show the hinge. Toula figured a right hinge, which consists of a slender anterior cardinal, a heavier middle cardinal (apparently broken), and a long, deeply bifid posterior cardinal. The pallial sinus is visible on several internal molds.

C. dariena dariena was widely distributed along the south and west edge of the Carribean Sea during lower and middle Miocene time and also in the eastern Pacific from Peru to Costa Rica. It has already been recorded from Brazil, Trinidad, Panama, Costa Rica, and Peru, and records are here given for Venezuela, Colombia, and Ecuador. Middle Miocene deposits carry the largest shells. Virtually all the specimens from lower Miocene beds are relatively small and grade almost imperceptibly into *C. dariena rabelli*.

The type of *C. dariena dariena* is apparently lost, as it is not in the United States National Museum among the types of the fossils described by Conrad in the reports of the Pacific Railroad explorations. The type specimen was collected by W. P. Blake, geologist of the surveying party under the command of Lieut. R. S. Williamson. Blake proceeded to San Francisco by way of the Isthmus of Panama and collected the type specimen and other fossils in a cut along the railroad "at Gatun, or Monkey Hill?" [25] Although the precise locality is a little uncertain it is of no great importance, as the Gatun formation, of middle Miocene age, is the only formation cropping out in this region. The specimen shown in Figure 10, Plate 14, is to be regarded as the neotype, at least until the original type is found. By this time topotypes are in many museums, for in the Canal Zone *C. dariena dariena* is very abundant in the lower part of the Gatun formation.

The only specimens from the Culebra formation of the Panama Canal Zone were collected from beds lying in the upper part 59 and 66 feet below the base of the Emperador limestone, according to MacDonald's section (stations 6019*d* and 6019*b*).[26] These specimens are very small and may not represent *C. dariena dariena*. The upper part of the Culebra formation seems to be Miocene (Aquitanian).

According to Maury's figure, *Clementia brasiliana* (pl. 14, fig. 11), based on specimens collected from lower Miocene beds in Brazil, seems to represent small specimens of *C. dariena dariena*. The specimens from Brazil are like small, slightly elongate shells of *C. dariena dariena* from Venezuela and other localities. Suites of specimens from the type locality of *dariena dariena* show that the shape of this species is too variable to introduce another name for small, slightly elongate Clementias from the lower Miocene beds of tropical America. At the anterior end of the shell the concentric waves of *C. brasiliana* are represented as erect frills, as in *Chione* (*Lirophora*), but this feature may have been exaggerated by the artist.

Type locality: Middle Miocene (Gatun formation), near Gatun, Panama Canal Zone.

Other localities: Lower Miocene (upper part of Culebra formation), west side of Gaillard Cut near Las Cascadas, bed 12*c* of section, Panama Canal Zone; D. F. MacDonald and T. W. Vaughan, collectors; station 6019*d*; one small specimen; identification doubtful. Lower Miocene (upper part of Culebra formation), same locality as 6019*d*, bed 11 of section; D. F. MacDonald and T. W. Vaughan, collectors; station 6019*b*; one small specimen; identification doubtful. Lower Miocene, Vamos-a-Vamos (now under water), Panama Canal Zone; R. T. Hill, collector; station 2682; one specimen. Lower Miocene, Sapote (or Zapote), Rio Revantazon, Costa Rica (Gabb). Lower Miocene, near San Andres, Department of Bolivar, Colombia; H. S. Gale and E. S. Bleeker, collectors; station 1/151; one small specimen. Lower Miocene, "Dam site" series, northwest of Agua Clara, Falcon, Venezuela; Ralph Arnold, collector; station 8071; one small specimen. Lower Miocene, Rio Coro, near coal mine at Isiro, 6 miles south of Coro, Falcon, Venezuela; Ralph Arnold, collector; station 6308; one small specimen. Lower Miocene, Guaico-Tamana road, Trinidad; two small specimens (Maury). Lower Miocene, Manzanilla, Trinidad; two small specimens (Maury). Lower Miocene (Estação formation), agricultural station on railroad from Braganca to Belem, 155 kilometers west of Braganca, Para, Brazil (Maury). Lower (?) Miocene, pit at well location of Standard Oil Co. of California near Bajada and Amen, Santa Elena Peninsula, Ecuador; H. S. Gale, collector; station 1/453; one small crushed specimen; identification doubtful. Lower Miocene, Santiago de Veraguas, Panama; O. H. Hershey, collector; one specimen.

[25] Blake, W. P., U. S. Pacific R. R. Expl., vol. 5 (33d Cong., 2d sess., H. Ex. Doc. 91), pt. 2, p. 1, 1855.

[26] MacDonald, D. F., The sedimentary formations of the Panama Canal Zone, with special reference to the stratigraphic relations of the fossiliferous beds: U. S. Nat. Mus. Bull. 103, pp. 537-538, 1919.

Lower Miocene, crest of divide along road to Aguadulce, about 5 miles northeast of Santiago de Veraguas, Panama; W. P. Woodring, collector; station 8465; one specimen. Lower Miocene, half a mile above Sulphur Spring, northwest of San Felix, Chiriqui Province, Panama; D. F. MacDonald, collector; station 6534; one broken specimen; identification doubtful. Lower Miocene, near San Felix, Chiriqui Province, Panama; Henri Pittier, collector; station 6262; one small specimen. Lower Miocene, Rio Papayal, first main fossil bed above *Pecten* shale, Chiriqui Province, Panama; J. T. Duce, collector; station 1/690; one small crushed specimen; identification doubtful. Lower Miocene, Rio Gualaca, 500 meters north of mouth, Chiriqui Province, Panama; J. T. Duce, collector; station 1/691; three small broken specimens; identification doubtful. Lower Miocene, *Conus* bed, road to Gualaca, Chiriqui Province, Panama; J. T. Duce, collector; station 1/715; one small crushed specimen; identification doubtful. Lower Miocene, Carballo Cliff, east of Punta Arenas, Costa Rica; J. D. Sears, collector; station 8330; one broken specimen; identification doubtful.[27] Lower Miocene, Caldera, near Corballo tunnel, Costa Rica; A. Alfaro, collector; station 5468; one specimen. Lower Miocene, Santa Maria de Dota, Quebrada Rivas, Costa Rica; J. F. Tristan, collector; station 7274; one specimen. Middle Miocene (Gatun formation), cut on relocated line of Panama Railroad, 1½ to 2 miles west of Camp Cotton toward Monte Lirio, Panama Canal Zone; D. F. MacDonald and T. W. Vaughan, collectors; station 6030; 17 specimens (topotypes), one of which (neotype) is figured. Middle Miocene (Gatun formation), lowest bed in cut on relocated line of Panama Railroad, one-quarter to one-half mile from Camp Cotton toward Monte Lirio, Panama Canal Zone; D. F. MacDonald and T. W. Vaughan, collectors; station 6029*a*; three specimens (topotypes). Middle Miocene (Gatun formation), basal part of section, half a mile from Camp Cotton toward Gatun, Panama Canal Zone; D. F. MacDonald and T. W. Vaughan, collectors; station 6031; two broken specimens (topotypes). Middle Miocene (Gatun formation) lower part of lowest bed in cut on relocated line of Panama Railroad about 3,500 feet south of Gatun railroad station, Panama Canal Zone; D. F. MacDonald and T. W. Vaughan, collectors; station 6033*a*; two specimens (topotypes). Middle Miocene (Gatun formation), same locality as preceding collection but from upper part of lowest bed; station 6033*b*; two specimens (topotypes). Middle Miocene (Gatun formation), same locality as preceding collection; D. F. MacDonald, collector; station 6004; one broken specimen (topotype). Middle Miocene (Gatun formation), cuts on railroad southeast of Gatun; A. A. Olsson, collector; station 8381; four specimens (topotypes). Middle Miocene (Gatun formation), first high cut on left side of railroad going from Gatun toward Panama, Panama Canal Zone; W. P. Woodring, collector; station 1/997; two specimens (topotypes). Middle Miocene (Gatun formation), Quebrancha Hills overlooking Gatun Lake, 1½ miles northeast of Gatun, Panama Canal Zone; D. F. MacDonald, collector; station 5845; three specimens. Middle Miocene (Gatun formation), near spillway of Gatun Dam, Panama Canal Zone; D. F. MacDonald, collector; station 5846; eight specimens, two of which are figured. Middle Miocene (Gatun formation), cuts west of Gatun Dam, Panama Canal Zone; A. A. Olsson, collector; station 8365; one unusually well preserved, small specimen. Middle Miocene (Gatun formation), west of Gatun Lake, Panama Canal Zone; A. A. Olsson, collector; station 8360; one broken specimen. Middle Miocene (Gatun formation), Nancys Cay, Bocas del Toro Province, Panama (Olsson). Middle Miocene (Gatun formation), upper Hone Creek and its tributary Sousi Creek, Costa Rica (Olsson). Middle Miocene (Gatun formation), Banana River, Costa Rica; D. F. MacDonald, collector; station 5882*l*; one specimen. Middle Miocene, edge of town of Balsanco, Cerro de San Antonio area, Department of Magdalena, Colombia; H. S. Gale, collector; station 1/927; one broken specimen; identification doubtful. Middle Miocene, near Tubara, Department of Atlantico, Colombia; F. A. Sutton and P. Squibb, collectors; station 1/987; two specimens, one of which is figured. Middle Miocene, Tubara, Department of Atlantico, Colombia; A. Iddings, collector; station 1/988; one specimen, figured. Middle Miocene, Villa Nueva, Department of Bolivar, Colombia; O. B. Hopkins, collector; station 1/101; four specimens. Middle Miocene (Zorritos formation), near Zorritos, Peru (Nelson, Woods, and Spieker). Middle (?) Miocene, Quebrada Las Ajontas, a mile above confluence with Rio Cristobal, Chiriqui Province, Panama; E. R. Smith, collector; station 7961; one specimen.

Type material: Neotype (both valves in attached position), U. S. Nat. Mus. No. 354038.

Subgenus EGESTA Conrad

Conrad, Fossils of the Tertiary formations of the United States, p. 70, 1845. (Reprint, Dall, under title "Conrad's fossils of the medial Tertiary of the United States," p. 70, 1893.)

Type (by monotypy): *Venus inoceriformis* Wagner, Acad. Nat. Sci. Philadelphia Jour., vol. 8, pp. 51–52, pl. 1, fig. 1, 1839. Middle Miocene, Maryland.

Shell relatively large, thin or heavy, inequilateral, upper posterior slope generally flattened or slightly concave, producing a truncate posterior end. Lunular area moderately or deeply depressed, otherwise poorly defined. Escutcheon poorly defined. Sculpture *Clementia*-like, consisting of coarse concentric waves and fine concentric threads, both of which may

[27] Romanes collected *C. dariena* at the Carballo Cliff (Romanes, J., Geology of a part of Costa Rica: Geol. Soc. London Quart. Jour., vol. 68, p. 125, 1912).

be replaced on the ventral part of the shell by growth lines. Resilium groove long, wide, and deep. Hinge of right valve consisting of a slender anterior cardinal, a heavier middle cardinal, and a slender, deeply bifid posterior cardinal; hinge of left valve consisting of a slender anterior cardinal, a heavy middle cardinal, and a very thin posterior cardinal. Pallial sinus narrow, deep, ascending, slightly tapering to an asymmetrically U-shaped apex.

Conrad casually gave the name *Egesta*, as a subgenus of *Venus*, to *Venus inoceriformis* and promptly forgot it. Apparently the name has been overlooked It is here proposed to use *Egesta* as a subgeneric name embracing several American fossils and two living species—*Clementia solida* Dall, from the Gulf of California, and *Clementia vatheliti* Mabille, from waters off Japan and Chosen.

The larger and heavier shell, flattened or concave upper posterior slope, accompanying truncation of the posterior end, longer and deeper resilium groove, heavier hinge, and narrower pallial sinus separate *Egesta* from *Clementia* s. s. A comparison of *Clementia papyracea* with *Clementia solida* (pl. 16, figs. 7, 8), which seems to be the culminating species of the subgenus *Egesta,* shows pronounced differences, but when other species are considered the separation of the subgenera is not so satisfactory. *Egesta* has a heavier hinge, a natural result of the heavier shell, and it is compressed into a relatively shorter space, so that the right posterior cardinal is not so far from the right middle cardinal and is less recumbent, and the left middle and posterior cardinals are less recumbent. According to the meager evidence available the American fossil species referred to *Clementia* s. s. have precisely the same kind of heavy compressed hinge. The pallial sinus of the American species of *Egesta,* both living and fossil, is very narrow, much narrower than in *Clementia* s. s., but *Clementia vatheliti,* which is here referred to *Egesta,* has a pallial sinus of intermediate width. The resilium groove of this species is not so wide as in the American species of *Egesta.* The niche in front of the anterior cardinal of living species of *Clementia* s. s. is almost eliminated in *Egesta* and in the American fossil *Clementia* s. s. on account of the greater thickness of the shell and hinge plate and the greater depression of the lunular area. The lunular area of *Clementia* (*Egesta*) *solida* is deeply depressed, its margin being thus brought almost parallel to the anterior cardinal, but this feature is not so pronounced in other species except the fossil *C.* (*E.*) *conradiana.*

The characteristic features of *Egesta* are less pronounced in the Miocene species *C.* (*E.*) *grayi* and *C.* (*E.*) *inoceriformis.* Their shells are not so heavy, the upper posterior slope is not so concave, the posterior truncation is not so pronounced, the lunular area is not so deeply depressed, and the pallial sinus is not quite so narrow. The living Japanese species *C.* (*E.*) *vatheliti* is more similar in these features to these two American Tertiary species than to *C.* (*E.*) *solida.* Dall[29] pointed out the similarity of *C.* (*E.*) *grayi* and *C.* (*E.*) *vatheliti.* On the basis of its narrow pallial sinus *Venus pertenuis,* a fossil species from California, is an *Egesta,* but its upper posterior slope is not flattened. *Venus conradiana* and *Venus martini* are considered Egestas, but their pallial sinus is not known.

MIOCENE SPECIES

Clementia (Egesta) grayi Dall

Plate 15, Figure 4

Clementia grayi Dall, Wagner Free Inst. Sci. Trans., vol. 3, pt. 5, p. 1193, pl. 37, fig. 12, 1900; pt. 6, p. 1236, 1903. Gardner, U. S. Geol. Survey Prof. Paper 142, p. 154, pl. 24, fig. 6, 1926.

Clementia cf. *dariena* Conrad. Dickerson and Kew, California Acad. Sci. Proc., 4th ser., vol. 7, table opposite p. 128, 1917.

Shell moderately large, thin or moderately heavy, very inequilateral. Upper posterior slope flattened or slightly concave, posterior end truncate. Lunular area moderately depressed. Sculpture consisting of coarse concentric waves and fine concentric threads, both of which are confined to about the umbonal third of adult shells and are replaced by irregular growth lines on the remainder of the shell. Hinge of right valve consisting of a slender anterior cardinal, a heavier middle cardinal, and a long, slender bifid posterior cardinal; hinge of left valve consisting of a slender anterior cardinal, a heavy middle cardinal, and a long, thin posterior cardinal; pallial sinus deep, narrow, ascending, slightly tapering to an acute apex.

Holotype: Length 63 millimeters, height 54 millimeters, diameter (left valve) 19 millimeters.

The holotype is an almost perfect left valve, though the hinge is defective. It is the only fully adult specimen discovered except two broken internal molds. The shell of the holotype is relatively thick, so thick that the concentric waves are not visible on the interior. It is the only shell that is so thick. The concentric waves are visible on the interior of a piece of shell collected at the same locality, but this thinner shell is smaller than the holotype. All the young shells are thin. The hinge of the right valve is known only from a small shell fragment collected at station 3856.

C. (*E.*) *grayi* is a characteristic *Egesta* and is similar to the living species *C.* (*E*).*vatheliti.* It is found in western Florida in the Chipola (lower Miocene), Oak Grove (lower Miocene), and Shoal River (middle Miocene) formations, and also in Mexico in the Tuxpan formation (lower Miocene). All the specimens from the Chipola formation are internal molds, except one

[29] Dall, W. H., Wagner Free Inst. Sci. Trans., vol. 3, pt. 6, p. 1236, 1903.

specimen collected at station 7151. The flattened upper posterior slope is very obscure on most of these molds and generally can not be seen at all on young specimens. The type locality of *grayi* is the only locality where it has been found in the Oak Grove sand. At one locality in the Shoal River formation (station 3856) it is very abundant, but none of the shells are full grown. The largest specimens from the Tuxpan formation of the Tampico embayment of Mexico are very similar to specimens from Florida, but it is more difficult to identify small specimens.

Type locality: Lower Miocene (Oak Grove sand), Yellow River, half a mile east of Oak Grove, Okaloosa County, Fla.; F. Burns, collector; station 2646; one specimen (holotype) and fragments of another specimen.

Other localities: Lower Miocene (Chipola formation), north bank of Tenmile Creek, at wagon bridge on road from Forestville to Marianna, Calhoun County, Fla.; C. W. Cooke and W. C. Mansfield, collectors; station 7151; one specimen. Lower Miocene (Chipola formation), Sopchoppy, Wakulla County, Fla.; G. C. Matson, collector; station 7468; seven specimens. Lower Miocene (Chipola formation), Bruce Creek just above Waldon Bridge, about 5 miles west of Redbay, Walton County, Fla.; W. C. Mansfield and W. M. Gomillion, collectors; station 1/979; two specimens. Lower Miocene (Chipola formation), near Rocky Landing, Choctawhatchee River, Washington County, Fla.; W. C. Mansfield and W. M. Gomillion, collectors; station 1/968; one specimen. Lower Miocene (Chipola formation), The Woodyard, three-fourths mile above Shell Landing, Holmes Creek, Washington County, Fla.; lower bed; J. A. Gardner, collector; station 1/609; one specimen. Lower Miocene (Chipola formation), Whites Creek, half a mile below bridge on road from Eucheeanna to Knox Hill, Walton County, Fla.; J. A. Gardner, collector; station 1/611; two specimens. Lower Miocene (Tuxpan formation), San Fernando, Tamaulipas, Mexico; W. F. Cummins, collector; station 4568; one broken internal mold. Lower Miocene (Tuxpan formation), 1 kilometer west of Temapache, Vera Cruz, Mexico; T. H. Kernan, collector; one specimen. Lower Miocene (Tuxpan formation), Huasteca Railroad, cut 10 kilometers from east terminus of railroad, District of Ozuluama, Vera Cruz, Mexico; T. W. Vaughan, collector; eight specimens. Middle Miocene (Shoal River formation), 5 to 6 miles west of Mossyhead, Walton County, Fla.; G. W. Nichols, collector; station 3856; 22 specimens. Middle Miocene (Shoal River formation), Folk's Creek, about 4 miles south of Argyle, Walton County, Fla.; T. W. Vaughan, collector; station 5192; one small specimen; identification doubtful. Middle Miocene (Shoal River formation), Shoal River, 1½ miles below Shell Bluff, Walton County, Fla.; T. W. Vaughan, collector; station 5193; one small specimen; identification doubtful. Same locality as preceding collection; station 5194; one specimen. Middle Miocene (Shoal River formation), Shoal River half a mile below Shell Bluff, Walton County, Fla.; T. W. Vaughan, collector; station 5079; one specimen.

Type material: Holotype (left valve), U. S. Nat. Mus. catalog No. 107381.

Clementia (Egesta) inoceriformis (Wagner)

Plate 15, Figures 5, 6

Venus inoceriformis Wagner, Acad. Nat. Sci. Philadelphia Jour., vol. 8, pp. 51–52, pl. 1, fig. 1, 1839.
Conrad, Fossils of the Tertiary formations of the United States, p. 70, pl. 40, fig. 1, 1845. (Reprint, Dall, under title "Conrad's fossils of the medial Tertiary of the United States," p. 70, pl. 40, fig. 1, 1893.)
Clementia inoceriformis (Wagner). Conrad, Acad. Nat. Sci. Philadelphia Proc., vol. 14, p. 575, 1863.
Dall, Wagner Free Inst. Sci. Trans., vol. 3, pt. 6, pp. 1235–1236, 1903.
Glenn, Maryland Geol. Survey, Miocene, pp. 315–316, pl. 82, figs. 1–2, 1904.
Clementia inoceramiformis (Wagner). Meek, Smithsonian Misc. Coll., vol. 7, No. 183, p. 10, 1864 (error for *inoceriformis*).

Shell medium sized, relatively thin, moderately inequilateral, anterior end extended. Upper posterior slope flattened, posterior end truncate. Lunular area deeply depressed. Sculpture consisting of coarse concentric waves and fine concentric threads; the waves are most pronounced on the dorsal half of the shell and may be absent on the ventral half. Hinge of right valve consisting of a slender anterior cardinal, a heavier middle cardinal, and a very slender bifid posterior cardinal; hinge of left valve consisting of a slender anterior cardinal, a heavy middle cardinal, and a very thin, long posterior cardinal. Pallial sinus deep, narrow, ascending.

Holotype: Length 75 millimeters, height 64 millimeters, diameter (left valve) 17 millimeters.

This species is the only *Clementia*-like mollusk found on the Atlantic coast of the United States north of Florida. Though it is recorded from the middle Miocene Calvert, Choptank, and St. Marys formations of Maryland, only a few specimens have been collected. An internal mold collected from the Calvert formation 1½ miles above Plum Point, on Chesapeake Bay (station 2457), closely resembles *grayi*, but the mold may be distorted. Two small hinges glued to the interior of the holotype are labeled "Shiloh, N. J." They probably represent small specimens of *inoceriformis*. If this locality label is trustworthy, these specimens represent the northernmost locality at which *Egesta* has been collected on the Atlantic coast. The internal mold from Gay Head, Mass., mentioned by Dall [30] as possibly representing this species seems to be some other veneroid mollusk, probably *Macrocallista*.

[30] Dall, W. H., Wagner Free Inst. Sci. Trans., vol. 3, pt. 6, p. 1236, 1903.

C. (*E.*) *inoceriformis* is similar to *grayi* but is larger and less inequilateral, and the flattening of its upper posterior slope is not so pronounced. The concentric waves of *inoceriformis* extend farther down on the shell.

Type locality: Middle Miocene (St. Marys formation), Portobello, St. Marys River, St. Marys County, Md.

Other localities: Middle Miocene (Calvert formation), clay bed below Plum Point marl member, 1½ miles above Plum Point, Calvert County, Md.; G. D. Harris, collector; station 2457; one specimen. Middle Miocene (Calvert formation), Hollin Cliff and Wye Mills, Calvert County, Md. (Glenn). Middle Miocene (Choptank formation), west shore of Choptank River, about one-fourth to one-half mile below Barker's Landing and about 5 miles southeast of Easton, Talbot County, Md.; F. Burns and G. D. Harris, collectors; station 2350*a*; one specimen, piece of left valve showing hinge. Middle Miocene (Choptank formation), Governor Run and Sand Hill, Calvert County, Md. (Glenn). Middle Miocene (St. Marys formation), Cove Point, Chesapeake Bay, Calvert County, Md.; Maryland Geol. Survey; three broken specimens. Upper Miocene (Shiloh marl member of Kirkwood formation), Shiloh, Cumberland County, N. J.; two specimens.

Type material: Holotype (left valve), Philadelphia Acad. Nat. Sci. catalog No. 4303.

Clementia (Egesta) conradiana (F. M. Anderson)

Plate 15, Figures 1, 2; Plate 17, Figures 4, 5

Venus (*Chione*) *conradiana* F. M. Anderson, California Acad. Sci. Proc., 3d ser., Geology, vol. 2, pp. 195–196, pl. 14 fig. 35, 1905.

Shell large, moderately elongate, very inequilateral, anterior end not extended, lunular area deeply depressed. Sculpture consisting of coarse concentric waves and fine concentric threads. Near the base of the shell the concentric waves and threads merge into growth lines. Pallial sinus not known.

Holotype (measurements based on Anderson's figure): Approximate length 90 millimeters, height 78 millimeters. Figured specimen from Santa Margarita formation: Length 74 millimeters, height 65 millimeters, diameter (both valves) 35 millimeters.

This species is not represented in the collections of the United States National Museum. The unfluted inner margin, described by Anderson, shows that it is neither a *Venus* nor a *Chione*. When this account was first written it was supposed that the holotype was destroyed in the San Francisco fire of 1906, but later information shows that it stood the ordeal. Doctor Hanna kindly sent the photographs reproduced as Figures 4 and 5 on Plate 17 and also a cast of the hinge. This material unexpectedly shows that, unlike the other fossil species from California, this species has a deeply depressed lunular area, though it has no definite lunule. It therefore seems to be similar to the living *C.* (*E.*) *solida*, but it is more inequilateral, and its upper slope is not concave. Plate 17 was added after this paper was in proof.

A specimen in the collections of the California Academy of Sciences (pl. 15, fig. 1) seems to represent *Venus conradiana*, as it is very inequilateral, but it was collected from the upper Miocene Santa Margarita formation.

According to Clark[31] and other writers, the Vaqueros formation of reports issued by the United States Geological Survey on the oil fields of central California embraces two faunal zones—a lower zone carrying *Turritella inezana*, which corresponds to Merriam's *Turritella hoffmanni* (= *T. inezana*) zone[32] and to Smith's Vaqueros fauna,[33] and an upper zone carrying *Turritella ocoyana*, which corresponds to Merriam's *Turritella ocoyana* zone and to Smith's "Temblor" fauna. Clark restricted the name Vaqueros (Vaqueros "group," as used by Clark) to the lower zone, and for the upper zone used the name "Temblor group," a name first proposed by F. M. Anderson[34] in the form "Temblor beds." In a recent publication on the geology of Ventura and Los Angeles Counties Kew[35] adopted the restriction of the name Vaqueros formation to the lower Miocene deposits carrying *Turritella inezana* and proposed the name Topanga formation for the middle Miocene beds carrying *Turritella ocoyana*. In the following list of localities and elsewhere in this report the beds in central California carrying *Turritella ocoyana*, which apparently are the equivalent of the Topanga formation, are referred to as the *Turritella ocoyana* zone.

Smith[36] recorded *C.* (*E.*) *conradiana* from both the lower Miocene Vaqueros fauna and the middle Miocene "Temblor" fauna.

Type locality: Middle Miocene (*Turritella ocoyana* zone), 3 miles east of La Panza Springs, San Luis Obispo County, Calif.[37]

Other localities: Lower Miocene (Vaqueros fauna), California (Smith). Upper Miocene (Santa Margarita formation), bed of small creek about 2 miles north of Santa Margarita, about 100 yards south of

[31] Clark, Bruce, The marine Tertiary of the west coast of the United States; its sequence, paleogeography, and the problems of correlation: Jour. Geology, vol. 29, pp. 595–600, 1921.

[32] Merriam, J. C., A note on the fauna of the lower Miocene of California: California Univ. Dept. Geology Bull., vol. 3, pp. 377–381, 1904.

[33] Smith, J. P., Geologic range of Miocene invertebrate fossils of California: California Acad. Sci. Proc., 4th ser., vol. 3, pp. 164–165, 1912.

[34] Anderson, F. M., A stratigraphic study in the Mount Diablo Range of California: California Acad. Sci. Proc., 3d ser., Geology, vol. 2, p. 170, 1905; A further stratigraphic study in the Mount Diablo Range of California: California Acad. Sci. Proc., 4th ser., vol. 3, pp. 18–20, 38–39, 1908.

[35] Kew, W. S. W., Geology and oil resources of a part of Los Angeles and Ventura Counties, Calif.: U. S. Geol. Survey Bull. 753, pp. 40–51, 1924.

[36] Smith, J. P., Geologic range of Miocene invertebrate fossils of California: California Acad. Sci. Proc., 4th ser., vol. 3, p. 178, 1912.

[37] Kew (U. S. Geol. Survey Bull. 753, p. 51, 1924) listed "*Venus* cf. *V. conradianus* Anderson" from the middle Miocene Topanga formation of southern California.

Mr. Meyer's house, San Luis Obispo County, Calif.; F. M. Anderson, collector; California Acad. Sci. station 74; one specimen, figured; identification doubtful.

Type material: Holotype (left valve), California Acad. Sci. catalog No. 2152.

Clementia (Egesta) martini (Clark)

Plate 15, Figure 3

Venus martini Clark, California Univ. Dept. Geology Bull., vol. 8, pp. 470–471, pl. 54, fig. 1, 1915.

Shell moderately large, elongate, moderately inequilateral. Sculpture consisting of coarse concentric waves and fine concentric threads. The waves extend to the base of the shell, but near the base they are more closely spaced. Hinge of left valve similar to left hinge of *pertenuis*. Pallial sinus not known.

Holotype: Length 63 millimeters, approximate height 50 millimeters, diameter (both valves) 32 millimeters.

This species also is not represented in the collections of the United States National Museum. The holotype is somewhat distorted, and no undistorted large specimens are available. A small undistorted topotype is suspiciously similar to *C.* (*E.*) *pertenuis*. Additional material may show that *martini* and *pertenuis* represent the same species. Two topotypes show broken left hinges that, so far as can be seen, are essentially similar to left hinges of *pertenuis*. As *C.* (*E.*) *martini* now stands, it is very similar to elongate specimens of *pertenuis* but apparently is more elongate and more inequilateral, though less inequilateral than *conradiana*.

According to Clark *C.* (*E.*) *martini* is found in the upper part of the San Pablo formation of Contra Costa County, Calif., and also in the Santa Margarita formation of the region north of Coalinga in beds carrying *C.* (*E.*) *pertenuis*.

Type locality: Upper Miocene (upper part of San Pablo formation), center of north edge of NW. ¼ sec. 28, T. 1 S., R. 1 E., Mount Diablo quadrangle, Contra Costa County, Calif.; Univ. California station 741.

Other localities: Upper Miocene (upper part of San Pablo formation), other localities in Contra Costa County, Calif. (Clark). Upper Miocene (Santa Margarita formation), north of Coalinga, Fresno County, Calif. (Clark).

Type material: Holotype (both valves in attached position), Univ. California Pal. Coll. catalog No. 11570.

MIOCENE AND PLIOCENE SPECIES

Clementia (Egesta) pertenuis (Gabb)

Plate 16, Figures 1–6

Venus kennerlyi Reeve? Gabb, California Geol. Survey, Paleontology, vol. 2, p. 22, pl. 5, fig. 37, 1866.[38]

Venus pertenuis Gabb, California Geol. Survey, Paleontology, vol. 2, pp. 22, 55–56, pl. 5, fig. 37, 1866.

Arnold, U. S. Geol. Survey Bull. 396, p. 17, pl. 8, fig. 3, 1909.

Arnold and R. Anderson, U. S. Geol. Survey Bull. 398, pp. 85, 86, pl. 30, fig. 3, 1910.

Venus (*Chione*) *pertenuis* Gabb. F. M. Anderson, California Acad. Sci. Proc., 3d ser., Geology, vol. 2, p. 195, 1905.

Shell relatively thin, reaching a large size; shape variable, slightly or decidedly elongate, slightly inequilateral, anterior end extended. Lunular area moderately depressed. Sculpture consisting of coarse concentric waves and fine concentric threads. Near the ventral margin the waves are lower and more closely spaced, or they may disappear. Hinge of right valve consisting of a slender anterior cardinal, a heavier middle cardinal, and a long, slender, deeply bifid posterior cardinal; hinge of left valve consisting of a heavy anterior cardinal, a slightly heavier middle cardinal, and a long, thin posterior cardinal. Pallial sinus deep, very narrow, ascending.

Holotype: Length 58 millimeters, height 52 millimeters, diameter (both valves) 24 millimeters. Topotype: Approximate length 62 millimeters, height 52 millimeters, diameter (both valves) 25.5 millimeters. Figured specimen from Santa Margarita formation: Length 79 millimeters, height 63 millimeters, diameter (both valves) 38 millimeters. Specimen figured by Arnold: Length 91 millimeters, height 75 millimeters, diameter (both valves) 44.6 millimeters.

The very narrow pallial sinus of this species indicates that it is an *Egesta*, although the upper posterior slope is not flattened, and therefore the posterior end is not truncate. Figure 2 on Plate 16 shows part of the pallial sinus impressed on the internal mold of a topotype and showing where the shell is broken. The hinge (pl. 16, figs. 5, 6) is visible on shells from Kern River, where, in contrast to other localities, the shells are beautifully preserved. The right posterior cardinal of the specimen shown in Figure 5 was broken after the description was written. So far as the hinge is concerned *C.* (*E.*) *pertenuis* closely resembles *grayi* and *inoceriformis*, but its left anterior cardinal is a little heavier, and its left middle cardinal is not quite so heavy.

The specimens shown on Plate 16, figures 2, 3, may be regarded as topotypes, as they were collected from the *Turritella ocoyana* zone in the general region of the type locality. Figure 3 represents a slightly elongate shell that closely resembles the holotype (pl. 16, fig. 1). Figure 2, which represents a more elongate shell collected at the same locality, shows that the shape is variable. Most specimens from the Santa Margarita formation are elongate. (See pl. 16, fig. 4.) Arnold figured a large elongate specimen from the *Turritella ocoyana* zone of the Coalinga district. The shell is also variable in thickness, but in virtually all specimens it is so thin that the concentric waves are impressed on internal molds.

[38] The title-page of this publication gives the date 1869, but according to the footnote on page xiv of the preface, section 1, part 1 (pp. 1–38), was published in 1866. I am indebted to Mr. Ralph B. Stewart for pointing out this discrepancy in dates. A copy of section 1, part 1, in the library of the Geological Survey bears the date 1866.

According to Smith,[39] *Venus pertenuis* is found in the Vaqueros, "Temblor," Santa Margarita, and Purisima faunas of California—that is, its range is lower Miocene to lower Pliocene. Apparently all the specimens in the collections of the United States National Museum are from the middle Miocene *Turritella ocoyana* zone and the upper Miocene Santa Margarita formation.

In the Santa Cruz folio [40] the Purisima formation is considered upper Miocene and Pliocene, but it is now generally regarded as of lower Pliocene age.

Type locality: "From the Miocene, at Griswold's on road to New Idria, Monterey County" [San Benito County, Calif.].

Other localities: Lower Miocene (Vaqueros fauna), California (Smith).[41] Middle Miocene (*Turritella ocoyana* zone), Griswold's, by Vallecitos Valley, San Benito County, Calif.; H. W. Turner, collector; station 213; one specimen (topotype). Middle Miocene (*Turritella ocoyana* zone), Griswoldville, Fresno County (apparently error for San Benito County), Calif.; H. W. Turner, collector; station 422; one specimen (topotype). Middle Miocene (*Turritella ocoyana* zone), Vallecitos Valley, San Benito County, Calif.; H. W. Turner, collector; station 424; four specimens (topotypes), two of which are figured. Middle Miocene (*Turritella ocoyana* zone), south side of the Vallecitos, 3½ miles due west of Ashurst place and about 1¼ miles south of Dixon Spring, SW. ¼ sec. 9, T. 17 S., R. 11 E., San Benito County, Calif.; Robert Anderson, collector; station 5815; two specimens (topotypes). Middle Miocene (*Turritella ocoyana* zone), *Turritella*-bearing bed on east flank of high hill northeast of Oil City, SE. ¼ NE. ¼ sec. 16, T. 19 S., R. 15 E., Fresno County, Calif.; Ralph Arnold and J. H. Pierce, collectors; station 4631; four specimens, one of which was figured by Arnold. Middle Miocene (*Turritella ocoyana* zone), *Turritella*-bearing bed about 11 miles north-northeast of Coalinga just below Big Blue serpentinous member in ridge in sec. 10, T. 19 S., R. 15 E., Fresno County, Calif.; Ralph Arnold, collector; station 4633; one specimen. Middle Miocene (*Turritella ocoyana* zone), reef beds one-fourth mile south-southeast of Barton's cabin, in NW. ¼ sec. 23, T. 25 S., R. 18 E., Devils Den district, Kern County, Calif.; Ralph Arnold, collector; station 4861; one specimen; identification doubtful. Middle Miocene (*Turritella ocoyana* zone), reef bed 1½ to 3 miles west of Painted Rock ranch, Carrizo Plain district, San Luis Obispo County, Calif.; Ralph Arnold, collector; station 5161; one specimen; identification doubtful. Middle Miocene (*Turritella ocoyana* zone), bluff on south bank of Kern River, 500 feet east of Barker's old ranch house, one-half mile north of Ant Hill, Kern County, Calif.; Robert Anderson, collector; station 6088; one specimen, figured. Middle Miocene (*Turritella ocoyana* zone), south bank of Kern River, along abandoned irrigation ditch about 300 yards east of old buildings at Barker's ranch, Kern County, Calif.; R. W. Pack and J. D. Northrop, collectors; station 6613; one specimen. Middle Miocene (*Turritella ocoyana* zone), north bank of Kern River, bluffs above irrigation ditch about 1¼ miles northeast of Rio Bravo ranch, Kern County, Calif.; R. W. Pack and A. T. Schwennesen, collectors; station 6623; one specimen, figured. Middle Miocene (*Turritella ocoyana* zone), about a mile southeast of Rio Bravo ranch, gullies draining southwestward from crest of 1,100-foot ridge due south of junction of Kern River and Cottonwood Creek, Kern County, Calif.; A. T. Schwennesen, collector; station 6611; one specimen. Middle Miocene (*Turritella ocoyana* zone), small arroyo tributary to Adobe Canyon, W. ½ sec. 36, T. 27 S., R. 28 E., Kern County, Calif.; R. W. Pack and A. T. Schwennesen, collectors; station 6627; six specimens. Middle Miocene (*Turritella ocoyana* zone), southwest slope of Pyramid Mountain, hard sandstone reefs just north of old road running east and west between Kern River and Poso Creek, Kern County, Calif.; J. D. Northrop and R. W. Pack, collectors; station 6638; one specimen. Middle Miocene (Topanga formation), Aliso Canyon, creek bed one-half to three-quarters mile southwest of A. Joughlin's place, Los Angeles County, Calif.; W. S. W. Kew and C. M. Wagner, collectors; station 8127 (Kew).[42] Middle Miocene (Topanga formation), trail eading southeastward from road over Santa Monica lMountains up Sierra Canyon, Los Angeles County, Calif.; W. S. W. Kew and C. M. Wagner, collectors; station 8135 (Kew).[42] Upper Miocene (Santa Margarita formation), Big Blue Hills, north bank of Domengine Creek, NE. ¼ sec. 33, T. 18 S., R. 15 E., Fresno County, Calif.; Robert Anderson and R. W. Pack, collectors; station 5833; four specimens, one of which is figured. Upper Miocene (Santa Margarita formation), Big Blue Hills, 2¼ miles northwest of Domengine place, SW. ¼ sec. 18, T. 18 S., R. 15 E., Fresno County, Calif.; Robert Anderson and R. W. Pack, collectors; station 5827; three specimens; identification doubtful. Upper Miocene (Santa Margarita formation), Big Blue Hills, 2½ miles northwest of Domengine place, about 1,000 feet northwest of station 5827, Fresno County, Calif.; Robert Anderson and O. P. Jenkins, collectors; station 5828; one specimen. Upper Miocene (Santa Margarita formation), Coalinga district, just above big oyster bed one-fourth mile northwest of Perliss well, Fresno County, Calif.;

[39] Smith, J. P., Geologic range of Miocene invertebrate fossils of California: California Acad. Sci. Proc., 4th ser., vol. 3, p. 174, 1912.

[40] Branner, J. C., Newsom, J. F., and Arnold, Ralph, U. S. Geol. Survey Geol. Atlas, Santa Cruz folio (No. 163), pp. 5-6, 1909.

[41] Kew (U. S. Geol. Survey Bull. 753, p. 46, 1924) listed "*Venus* cf. *V. pertenuis* Gabb" from the Vaqueros formation of southern California (station 8137). This collection is not in the United States National Museum at the present time.

[42] These collections are not in the United States National Museum at the present time.

Ralph Arnold, collector; station 4848; two specimens. Upper Miocene (Santa Margarita formation), Tejon Hills, Kern County, Calif. (Nomland [43]). Lower Pliocene (lower part of Purisima formation), Santa Cruz quadrangle, Calif. (Branner, Newsom, and Arnold [44]).

Type material: Holotype (both valves in attached position), Univ. California Pal. Coll. catalog No. 12000.

Doubtful species

The following descriptions, which were added after this account was in proof, may represent *Clementia*, but the species can not now be certainly identified.

Astarte dubia D'Orbigny

Plate 17, Figures 1, 2

Astarte dubia D'Orbigny, Voyage dans l'Amérique méridionale, Paléontologie, vol. 3, pt. 4, p. 105, 1842; vol. 8, pl. 6, figs. 12, 13, 1847.

According to D'Orbigny's figures, which are here reproduced, this species may be a *Clementia*. The dimensions given are as follows: Length 38 millimeters; height, 33 millimeters; diameter, 20 millimeters. The following is a free translation of D'Orbigny's statement concerning this species:

> I will not consider the age or locality of this species. I found it in a collection at Chuquisaca, and I was told that it came from Peru. It belongs, I think, to the Cretaceous terrains of these regions.

Though Chiquisaca is probably in the interior of Peru, it should be noted that D'Orbigny states that he found this specimen in a collection at Chuquisaca, not from Chuquisaca. It may possibly have been collected from the Tertiary beds in the coastal region of northwestern Peru, though, according to the figures, it is not the same as either of two undescribed Eocene and Oligocene species from Peru, specimens of which Doctor Olsson kindly sent me.

[43] Nomland, J. O., Fauna of the Santa Margarita beds in the North Coalinga region, Calif.: California Univ. Dept. Geology Bull., vol. 10, p. 302, 1917.

[44] Branner, J. C., Newsom, J. F., and Arnold, Ralph, U. S. Geol. Survey Geol. Atlas, Santa Cruz folio (No. 163) p. 6, 1909.

Venus brioniana Trask

Plate 17, Figure 3

Venus brioniana Trask, California Univ. Dept. Geology Bull., vol. 13, p. 151, pl. 5, fig. 1, 1922.

Mr. Ralph B. Stewart called my attention to this species, which otherwise would have been overlooked. The holotype is an internal mold of a right valve, with part of the shell attached, impressed on coarse detrital rock. It has a length of about 87.7 millimeters and a height of about 88.5 millimeters. So far as can be seen, this specimen is virtually undistorted. It has a trigonal shape and is only slightly inequilateral. The sculpture consists of *Clementia*-like waves that become obscure on the lower half of the shell. It can not be seen whether the shell has a lunule, and all the internal features are inaccessible.

This specimen is less inequilateral and has a greater relative height than any large specimens of *Clementia* (*Egesta*) *pertenuis* examined, though it is quite similar on an enlarged scale to slightly elongate shells of this species, such as the topotype shown in Plate 16, Figure 3. Although this species is probably an *Egesta*, its disposition must await additional material. It has a much greater relative height than the holotype of *Clementia* (*Egesta*) *martini*, which, however, is crushed, so that comparisons based on that specimen are unreliable. According to Trask, both *Clementia* (*Egesta*) *martini* and *Venus brioniana* are found in the Briones sandstone. They may represent the same species, and both may be the same as *C.* (*E.*) *pertenuis*. There is no doubt that the outline of *pertenuis* is variable. As it is found in the Santa Margarita formation it would not be surprising to find it in beds lying between the Santa Margarita formation and the *Turritella ocoyana* zone. In Trask's photograph the shell is not correctly oriented and therefore appears too inequilateral.

Type locality: Upper Miocene (Briones sandstone), Concord quadrangle, Calif.; Univ. California station 177.

Type material: Holotype (right valve), Univ. California Pal. Coll. catalog No. 12377.

PLATES 14–17

PLATE 14

[All figures natural size except as otherwise indicated]

	Page
FIGURES 1, 2. *Clementia (Clementia) dariena vetula* Woodring, n. subsp. Holotype. Middle Eocene, southeast of Pijaguay, Colombia, station 1/986. U. S. Nat. Mus. catalog No. 354036	33
3, 4. *Clementia (Clementia) dariena vetula* Woodring, n. subsp. Paratypes. Same locality. U. S. Nat. Mus. catalog No. 354037	33
5. *Clementia (Clementia) dariena rabelli* Maury. Holotype. Middle Oligocene (San Sebastian shale), near San Sebastian, Porto Rico. Am. Mus. Nat. Hist. Div. Geol. and Invertebrate Pal. catalog No. 22509	34
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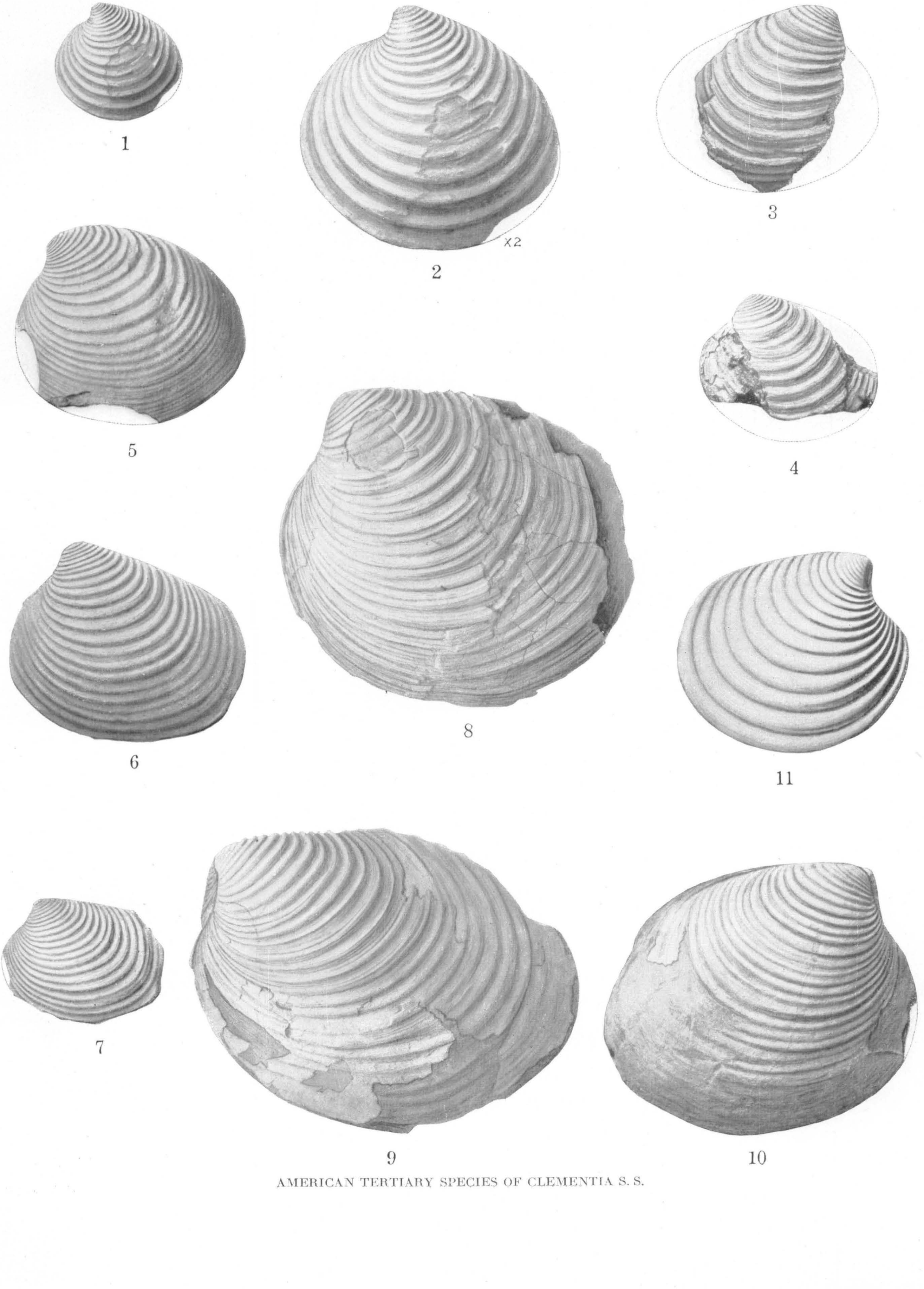

AMERICAN TERTIARY SPECIES OF CLEMENTIA S. S.

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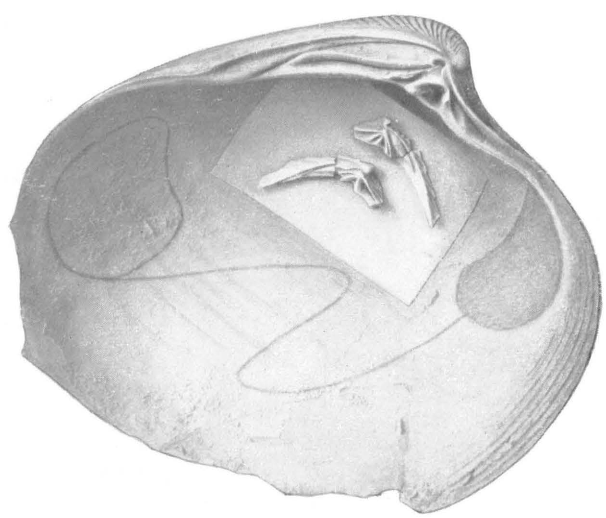

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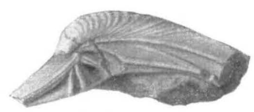

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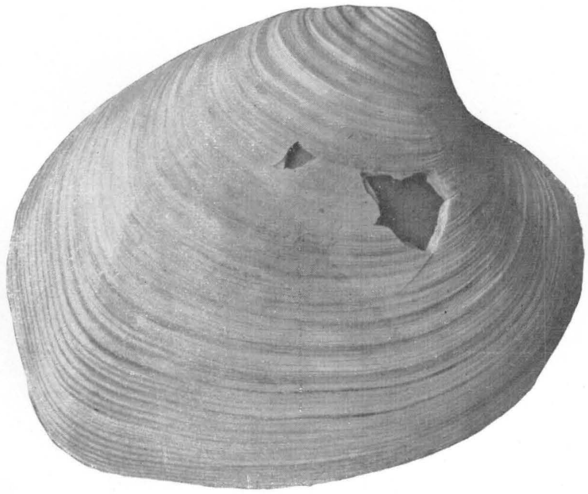

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AMERICAN TERTIARY AND LIVING SPECIES OF EGESTA

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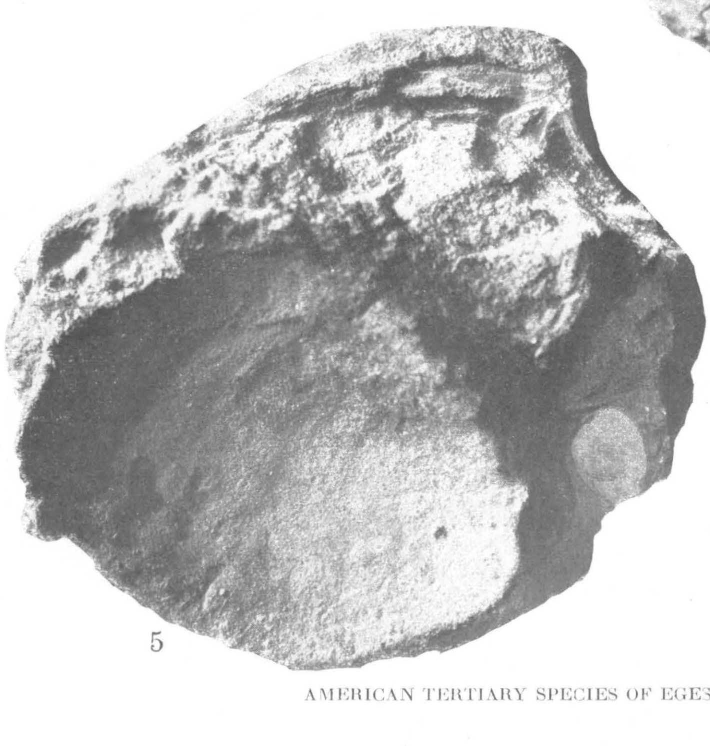

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