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GEOLOGIC RELATIONS OF THE GILA CONGLOMERATE IN SOUTHEASTERN ARIZONA.[1]

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ABSTRACT.

Fossils recently collected from the Gila and San Simon valleys, southeastern Arizona, include remains of mammals, fresh-water invertebrates, diatoms, and silicified wood. The lake beds in which the fossils occur belong to the Gila conglomerate as originally defined by Gilbert, and at least a part of that formation is proved by the mammalian remains to be upper Pliocene in age. Deposits containing upper Pliocene vertebrate fossils in the San Pedro valley, Arizona, may now be referred with confidence to the Gila conglomerate, and assignment thereto of detrital deposits occurring in many valleys in southeastern Arizona and southwestern New Mexico is rendered less hazardous than heretofore. The intense deformation of many Miocene (?) rocks of the region and the relatively undisturbed condition of the Pliocene deposits indicate that the latest major deformation, which may have been the cause of ponding of water in the valleys, occurred in late Miocene or early Pliocene time. Stratified tuffs that occur in the lake beds indicate upper Pliocene volcanic activity in the vicinity. The climate of the region during the part of the upper Pliocene represented was possibly mild and humid, but the part of Pleistocene history represented, as indicated by extensive pediment-cutting, is characterized by erosion under arid conditions.

INTRODUCTION.

The purpose of this paper is to present new geological data on the Gila and San Simon valleys, southeastern Arizona, together with interpretations relating primarily to the Gila conglomerate, which seem likely to aid in deciphering the Tertiary and Quaternary history of this and neighboring regions. The data were gathered by the writer in connection with an investigation carried on in the winter of 1933-1934 by the United States Geological Survey.

The writer acknowledges his indebtedness to C. L. Gazin, of the U. S. National Museum, and W. C. Mansfield, K. E. Lohman, and R. W. Brown, of the U. S. Geological Survey, for reports on the fossil collections; and to N. H. Darton,

[1] Published by permission of the Director of the United States Geological Survey.

O. E. Meinzer, G. A. Waring, B. N. Moore, Miss M. G. Wilmarth, P. B. King and other members of the U. S. Geological Survey for valuable suggestions.

GEOGRAPHY.

The Gila and San Simon valleys in southeastern Arizona together form a single great structural trough, trending northwestward from Hidalgo County, New Mexico, to the neighborhood of the Coolidge dam. This trough, which is about 150 miles long, is bordered on the southwest by the Chiricahua, Dos Cabezas, Graham, Santa Teresa, Turnbull and Mescal mountain ranges, and on the northeast by the Peloncillo and Gila ranges. The highest peak in these mountains is Mount Graham, in the Graham Mountains, with an altitude of 10,720 feet. The lowest point in the valley trough is at the Coolidge dam, where the altitude is about 2,400 feet.

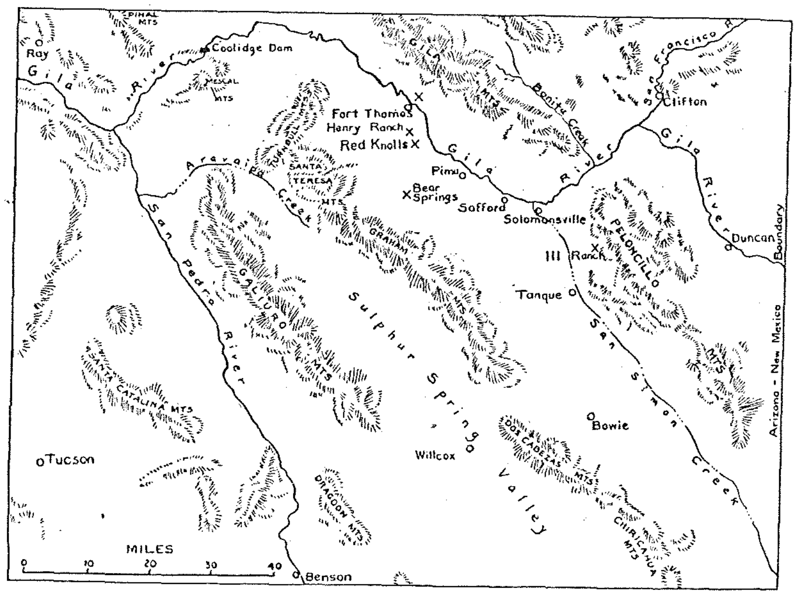

Fig. 1. Map of part of southeastern Arizona, showing location of the Gila and San Simon valleys. Fossil localities discovered by the writer are marked "X."

The Gila River, a perennial stream, enters the trough northeast of Solomonsville, Arizona, through a gorge in the Peloncillo Mountains, and flows northwestward down the Gila valley to the Coolidge dam where it turns southwest and leaves the valley through a gorge in the Mescal Mountains. San Simon Creek, an intermittent stream, rises at the head of the trough and flows northwestward down the San Simon valley to join the Gila at Solomonsville.

GEOLOGY AND GEOMORPHOLOGY.

General Description.—The rocks exposed in the mountain ranges bordering the trough have not been studied in detail. Those of the mountains on the southwest side are largely metamorphic rocks and intrusive igneous rocks ranging in age from pre-Cambrian to Tertiary. Those exposed northeast of the trough are principally Tertiary lava flows and tuffs. The trough itself contains detrital valley fill of Tertiary and Quaternary age, the geologic relations of which form the principal topic discussed in this paper.

The trough may be defined by faults along the valley margins, though no faults are visible because of concealment of the older rocks beneath overlapping deposits of valley fill. The surface of the area underlain by the valley fill, which is about 15 miles wide at Safford, slopes from each side toward the center of the trough in a succession of steps, or terraces, to be described. The margin of the valley fill on each side is marked by an abrupt change in grade at the base of the steep mountain slopes, except in a few small areas at the base of the Graham Mountains where pediments have been cut on crystalline rocks as well as on valley fill.

Gila Conglomerate.—The most extensive deposits exposed in the valley trough belong to a system of lake beds which lie nearly horizontal and consist mainly of gray and red clays, gypsiferous in places, that locally contain tongues and lenses of sandstone, tuff, limestone, and diatomite. The lacustrine origin of these deposits is inferred from (1) the character of the diatom floras, (2) the presence of thin limestone beds containing fresh-water molluscan fossils, (3) the rather extensive layers of tuff, which must have been laid down in quiet water, and (4) the predominance of clay beds. The beds of this facies, however, generally underlie only the central parts of the valley and merge into deposits of equivalent age of a coarser facies that underlie extensive belts along the margins of the valley trough, as shown in Fig. 2. The deposits of both phases are herein included in the Gila conglomerate for reasons which will be stated. The strata of the marginal facies are largely composed of extremely coarse fanglomerate made up of subangular to angular pebbles, cobbles, and boulders of rock derived from the neighboring mountains. This interpretation, which implies that the rocks of both phases are equivalent in age, differs from that proposed for this valley

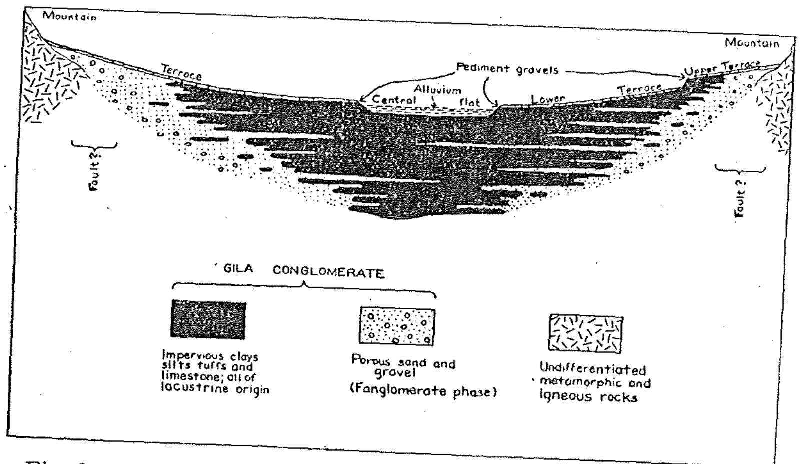

Fig. 2. Interpretative cross-section of the Gila valley near Safford, Arizona, looking southeastward.

trough by Schwennesen,[2] who regarded the fanglomerate beds along the valley margins in the San Carlos Indian Reservation as belonging to an older formation extending across the trough beneath about 600 feet of lake beds. No such relation is revealed by the records of several deep wells drilled unsuccessfully for oil in recent years in the central part of the valley trough in Graham County, all of which penetrate mainly fine-grained material. One well was drilled near Pima to a depth of 3,767 feet without encountering any thick succession of conglomerate beds comparable with the fanglomerates exposed along the valley margins.

[2] Schwennesen, A. T.: Geology and water resources of the Gila and San Carlos valleys in the San Carlos Indian reservation, Arizona: U. S. Geol. Survey Water-Supply Paper 450, p. 5 and fig. 2, 1919.

Schwennesen's description and interpretation of the land forms in the part of the trough lying in the San Carlos Indian Reservation are as follows:

"On the north and south sides of the basin, adjacent to the mountains, are belts of hilly country which stand higher than the middle of the basin and which have evidently been produced by the erosion of what were at one time smooth alluvial slopes extending from the mountains toward the middle of the basin. Inside these hilly belts are belts of lower country which are the remnants of a lake bottom that once extended across the axis of the basin. This lake apparently came into existence after the alluvial slopes had been considerably eroded. As a result of the large amount of sediment deposited in the lake its bottom became smooth and had only gentle slopes toward the middle of the basin. Although this former lake bottom has been eroded since the disappearance of the lake, it still forms a strong contrast to the more anciently dissected marginal belts."

The marginal belts and the more central gently sloping terraces referred to are recognized by the present writer as surfaces developed by planation, or mountain pediments. Furthermore, the dissected upper surface of the high marginal belt, or pediment, on the southwest side of the Gila valley along the base of the Graham Mountains, near Safford, is underlain in part by lake beds, in part by fanglomerate and, in an area of a few square miles, by the crystalline rocks of the Graham Mountains. Coincidence of the limits of the "belts of lower country" with the outlines of the former lake is thus contradicted insofar as the part of the valley lying within Graham County is concerned. Moreover, if the fanglomerates and lake beds had been deposited at separate times the transition from coarse detrital material in the basin deposits near the margins of the trough to predominantly fine-grained material in the central part of the trough would presumably be abrupt. This transition, as seen along several arroyos, occurs not abruptly but gradually. Interfingering of the two types of fill, as shown in Fig. 2, is inferred from well data and is supported by hydrologic considerations. The present writer concludes that the Gila conglomerate as a geologic formation includes both the lake beds and fanglomerates, the two phases having been deposited simultaneously.

Age and Correlations.—Gilbert,[3] who first described the Gila

[3] Gilbert, G. K.: U. S. Geog. Surveys W. 100th Mer., vol. 3, pp. 540-541, 1875.

conglomerate, made the following statement regarding the deposits that make up that formation:

"Beginning at the mouth of the Bonita, *below which point their distinctive characters are lost*, they follow the Gila for more than 100 miles toward its source, being last seen a little above the mouth of the Gilita. . . . . Below the Bonita it [the Gila conglomerate] merges insensibly with the detritus of Pueblo Viejo Desert."

The deposits originally described as Gila conglomerate therefore include the lake beds and marginal fanglomerates of the Gila and San Simon valleys (referred to in the preceding quotation as the "Pueblo Viejo Desert"). Widely scattered deposits in the valleys of southeastern Arizona and southwestern New Mexico have from time to time been correlated with the Gila conglomerate on the basis of lithologic resemblance and similar mode of occurrence. Upper Pliocene vertebrate fossils collected by the present writer in the lake beds of the Gila and San Simon valleys at localities about 30 miles apart (Fig. 1) definitely establish the geologic age of at least a part of the Gila conglomerate as exposed in those valleys, and warrant its correlation with deposits of the same general age in the San Pedro valley, where Kirk Bryan made upper Pliocene mammalian fossil collections which were augmented and described by J. W. Gidley. Since the principal deposits exposed in these two troughs, which are separated by two ranges of mountains (see Fig. 1), are therefore more or less equivalent in age, it may be inferred that many of the thick valley deposits that have been described as Gila conglomerate belong in reality to a common period of deposition. The uncertainty which has heretofore attended the assignment of these scattered deposits to the Gila conglomerate is as a result somewhat diminished, and on the basis of fossil evidence the Gila conglomerate must, in part at least, be assigned to the Upper Pliocene. However, some of the deposits along the upper Gila River and its tributaries that were included by Gilbert in the Gila conglomerate may be Pleistocene.

Fossils.—The vertebrate fossils collected by the writer from the lake beds of the Gila and San Simon valleys include camel bones, peccary teeth, a sloth bone, teeth and bones belonging to at least two genera of horses, and a number of fragments of a large turtle. These, together with photographs and casts of part of a mastodon skull from a third locality, have been referred for determination to C. L. Gazin of the United States National Museum, whose preliminary report follows:

"1. 111 Ranch, sec. 27, T. 8 S., R. 28 E.
   Hipparion (Nannippus) sp. (teeth and jaw fragments).
   Equid, large form (tooth fragments and foot bones).
   Camelid sp. (limb fragments and foot bones).
   Platygonus sp. (teeth).
   Megalonychid sp. (ungual phalanx).
2. Henry Ranch, NE. ¼, sec. 22, T. 5 S., R. 23 E.
   Plesippus sp. (teeth and bone fragments).
   Camelid sp. (fragmentary foot bones).
3. Bear Springs, SE. ¼, sec. 9, T. 7 S., R. 23 E.
   Rhynchotherium? sp. (portion of skull with teeth, identified from photographs and casts of the tooth crowns).

"It is probable that little or no time difference exists between the above three occurrences, as the presence of *Nannippus*, *Plesippus* and a mastodon resembling *Rhynchotherium* in each case indicates an upper Pliocene age. The part of the upper Pliocene represented is not clearly indicated although the part represented appears to be less advanced than the *Plesippus* horizon at Hagerman, Idaho,[4] and probably not greatly separated in time from the Blanco of Texas.[5] Compared with the horizons producing mammalian remains in the San Pedro valley of Arizona,[6] the occurrences in the Gila and San Simon valleys may be older than the late Pliocene or Pleistocene at Curtis Ranch, about 15 miles south of Benson, Arizona, and younger than, or possibly equivalent to, the upper Pliocene recognized near Benson.

"The turtle remains were submitted to C. W. Gilmore for identification and he reported them as undeterminable testudinate remains with no indication as to age."

[4] Gidley, J. W.: A new Pliocene horse from Idaho: Jour. Mammalogy, vol. 11, no. 3, pp. 300-303, 1930; Continuation of the fossil horse round-up on the Old Oregon Trail: Smithsonian Inst., Explorations and field work in 1930, pp. 33-40, 1931; Boss, N. H.: Explorations for fossil horses in Idaho: Smithsonian Inst., Explorations and field work in 1931, pp. 41-44, 1932.

[5] Gidley, J. W.: The fresh-water Tertiary of northwestern Texas: Am. Mus. Nat. Hist., Bull., vol. 19, pp. 617-635, 1903; Cope, E. D.: A preliminary report on the vertebrate paleontology of the Llano Estacado: Texas Geol. Survey, 4th Annual Report, part 2, pp. 47-74, 1893; Plummer, F. B.: Cenozoic systems in Texas, in Geology of Texas, Univ. Texas Bull. 3232, vol. 1, pp. 765-776, 1932.

[6] Gidley, J. W.: Preliminary report on fossil vertebrates of the San Pedro valley, Arizona, with descriptions of new species of *Rodentia* and *Lagomorpha*: U. S. Geol. Survey Prof. Paper 131, pp. 119-131, 1922; Fossil *Proboscidea* and *Edentata* of the San Pedro valley, Arizona: U. S. Geol. Survey Prof. Paper 140, pp. 83-95, 1926.

Fossil invertebrates from a fourth locality in the lake beds were studied by W. C. Mansfield of the U. S. Geological Survey, whose statement follows:

4. Red Knolls, sec. 36, T. 5 S., R. 23 E. From a limestone bed about 40 feet higher than unidentified vertebrate bones.
   Lymnaea? sp. (Only a fragment of a spire seen.)
   Planorbis sp. (Species indeterminable; specimens badly crushed).

"The fauna lived under fresh-water conditions. The age is indeterminable because of the poor stage of preservation of the organisms; however, they do not look very old."

Fossil wood from the Henry Ranch has been studied by R. W. Brown of the U. S. Geological Survey, who writes as follows:

"Among several specimens of silicified wood from sec. 22, T. 5 S., R. 23 E., Graham County, Ariz., only one was well enough preserved to show identifiable cellular elements. A transverse section of this wood exhibits distinct annual rings composed of about equal zones of spring and summer wood. The vessels of the spring wood are large and uniform; those of the summer wood, minute. The transition from the open spring wood to the dense summer wood is conspicuously abrupt. The medullary rays are narrow, barely visible to the naked eye, and lie between single, rarely double, rows of vessels. The radial and tangential sections reveal nothing definitive. This wood is clearly a ring-porous, dicotyledonous species, resembling in some respects the living *Sassafras variifolium*. I should hesitate, however, to identify it positively as a *Sassafras*. Its well-defined annual rings suggest regular seasonal changes, either wet to dry or warm to cold, or both. As to its geological age I can offer only a guess that it may have lived in the middle or late Tertiary."

Diatomite from two localities was examined by K. E. Lohman, whose report follows:

"U.S.G.S. Diat. Loc. No. 2054, 111 Ranch, Arizona, SE. ¼, sec. 21, T. 8 S., R. 28 E.

"This material consists chiefly of volcanic ash and some clastic material, diatoms constituting only about 30 per cent of the total. It is useless for any purpose for which diatomite would be required. The following species of diatoms are present:

Melosira italica (Ehrenberg) Kützing	F
Podosira sp.	R
Stauroneis cf. S. phoenicenteron Ehrenberg	F
Anomoeoneis sphaerophora (Kützing) Pfitzer	F

Navicula cf. N. cuspidata Kützing	R
Navicula amphibola Cleve	F
Pinnularia major (Kützing) Cleve	C
Pinnularia microstauron (Ehrenberg) Cleve	F
Gomphonema longiceps Ehrenberg var. subclavata Grunow	R
Denticula elegans Kützing	C
Epithemia zebra (Ehrenberg) Kützing var. porcellus (Kützing) Grunow	R
Rhopalodia gibberula (Ehrenberg) Müller	F
Nitzschia sp.	R
Campylodiscus clypeus Ehrenberg	R

"U.S.G.S. Diat. Loc. No. 2055, opposite Fort Thomas, Arizona, SE. ¼, sec. 24, T. 4 S., R. 23 E.

"This material is an impure diatomite, the impurities, chiefly silt, amounting to approximately 15 per cent. It would be suitable for such purposes as heat and sound insulation, but would not be marketable in competition with even medium grades of diatomite from California, Oregon, Nevada, etc., due to impurities. Its economic use would depend on a local market, for which its use as heat insulation is suggested. The following species of diatoms are present:

Cyclotella meneghiniana Kützing	C
Mastogloia cf. M. smithii Thwaites	F
Gomphonemia cf. G. lanceolatum Ehrenberg	F
Denticula elegans Kützing	A
Surirella striatula Turpin	F
Campylodiscus clypeus Ehrenberg	F

A—Abundant
C—Common
F—Few
R—Rare

"The diatoms found in both of these samples suggest that they were deposited in warm, somewhat saline lake waters. All of the species are living at the present time, so that no evidence of age is offered, other than that the deposits can hardly be very old. All of these species have been found in rocks of supposed Pliocene age, so that these deposits may be Pliocene or younger."

Pre-Gila Deformation.—The Gila fanglomerates and lake beds in the valley trough that has been described have undergone very little deformation and in general lie nearly horizontal. This is true of most of the deposits in Arizona and New

Mexico that have been described as Gila conglomerate, though in the Ray quadrangle Ransome[7] tentatively assigned to that formation beds that are steeply tilted which at first sight he had believed to underlie the Gila unconformably. In the Aravaipa Valley, according to Ross,[8] the relatively undisturbed Gila conglomerate rests unconformably on steeply upturned Miocene (?) beds of lava and tuff interbedded with conglomerate and sandstone. These beds may be equivalent to the Miocene (?) beds of the Santa Cruz valley near Tucson, which are also greatly deformed, and to the Whitetail conglomerate[9] of the Ray and Globe quadrangles. It is inferred from these data that the latest deformation of mountain-building proportions that affected this region occurred prior to the deposition of the Gila conglomerate, in late Miocene or early Pliocene time. It was possibly as a result of that deformation that water became ponded in several valleys during the late Pliocene to form lakes of the type described in this paper.

Late Pliocene climate and volcanic activity.—During the part of the Pliocene represented by the exposed basin deposits the climate of the region was apparently more or less humid and warm, as indicated by the mammalian[10] and fresh-water molluscan faunas, the diatom floras and the fossil wood.[11] The occurrence of tuffs in the lake beds indicates that volcanoes were active near by, and part of the great mass of volcanic rocks exposed in the neighboring mountains is probably due to this activity.

Post-Gila Pediments.—Near the close of the Pliocene or possibly in early Pleistocene time the ponded water in the valley trough found an outlet at the site of the Coolidge dam and drained away, exposing to erosion the Gila lake beds and conglomerates, and the Pleistocene history of the region, so far as it is revealed, is largely a history of erosion. At some time after the lake was drained a climatic change occurred and moist conditions gave way to aridity, as the earliest post-lake erosion surface for which evidence exists is of the pedi-

[7] Ransome, F. L.: The copper deposits of Ray and Miami, Arizona: U. S. Geol. Survey Prof. Paper 115, pp. 71-74, 1919.

[8] Ross, C. P.: Geology and ore deposits of the Aravaipa and Stanley mining districts, Graham County, Arizona: U. S. Geol. Survey Bull. 763, pp. 29-31, 1925.

[9] Ransome, F. L.: Idem, pp. 67-68, 1919.

[10] Gidley, J. W.: Preliminary report on fossil vertebrates of the San Pedro valley, Arizona, with descriptions of new species of *Rodentia* and *Lagomorpha*: U. S. Geol. Survey Prof. Paper 131, p. 121, 1922.

[11] Brown, R. W.: Oral communication to the writer.

ment[12] type. Such sloping piedmont plains are characteristically formed by erosion in desert regions. The typical pediments of the Papago country, however, are surfaces formed in enclosed basins under arid conditions by erosion of the rocks composing mountain blocks, whereas the surfaces here described, although produced by similar processes, were cut almost entirely on unconsolidated fill in a basin in which through drainage was maintained. As the products of erosion while the pediments were being formed were carried downstream and out of the Gila-San Simon trough, the base level in the trough was lowered. This circumstance probably accounts for the absence in the Gila and San Simon valleys of the "sub-alluvial bench" of Lawson,[13] a feature characteristically associated with pediments formed while the base level is rising, owing to accumulation of detritus in an enclosed basin. Consequently the pediments that slope downward from both sides of the relatively undissected upper part of the San Simon valley as described by Schwennesen,[14] flatten out and meet in the central part of the basin. In an area of a few square miles in the northwestern part of T. 10 S., R. 20 E., the pediment is developed on the crystalline rocks of the Graham Mountains.

The Gila fanglomerates and lake beds on which pediments are cut are capped by a thin veneer of coarse caliche-cemented débris containing well rounded to sub-angular pebbles, cobbles, and boulders of materials similar to the fanglomerates of the Gila. Since this material overlies the late Pliocene beds unconformably and is older than the thick deposits of alluvium along the Gila River, it is tentatively regarded as Pleistocene. It may be equivalent in age to some of the deposits that have been assigned to the Gila conglomerate in other valleys in this region, though the name Gila is generally applied only to deposits of great thickness. Two pediments are represented by the sloping débris-covered upper surfaces of the conspicuous terraces on the southwest side of the Gila valley

[12] Bryan, Kirk: The Papago country, Arizona: U. S. Geol. Survey Water-Supply Paper 499, pp. 93-101, 1935; Koschmann, A. H., and Loughlin, G. F.: Dissected pediments in the Magdalena district, New Mexico; Bull. Geol. Soc. Am., vol. 45, pp. 463-478, 1934.

[13] Lawson, A. C.: Epigene profiles of the desert: University of California Publications, Geology, IX, pp. 23-48, 1915; Field, R.: Stream carved slopes and plains in desert mountains: this Journal, vol. 29, no. 172, pp. 313-322, 1935.

[14] Schwennesen, A. T.: Ground water in San Simon valley, Arizona and New Mexico: U. S. Geol. Survey Water-Supply Paper 425-A, p. 5, 1917.

near Safford. The lower, and therefore the younger, of these surfaces is matched by an extensive terrace on the opposite side of the valley, but the higher is there less well marked, being represented only by a few gravel-capped mesas in sec. 31, T. 5 S., R. 25 E., that stand about 100 feet above the lower surface. The lower terrace, as projected across the central flat, is about 100 feet higher than the Gila River.

The pediments are believed to represent intervals of relatively slow cutting by the Gila River through the gorge below the Coolidge dam site. These intervals were separated in time by a stage during which the cutting progressed more rapidly.

Quaternary alluvium.—The events that have been described were followed by renewed acceleration in the rate of cutting by the Gila River, which resulted in excavation in the lake beds of the broad trench, 1 to 3 miles wide, in which the late Quaternary alluvial deposits underlying the agricultural lowland plain along the river have accumulated. These deposits have a maximum thickness of about 150 feet and are overlain by Recent alluvium on the present river flood plain.

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MULTIPLE GRINDING OF THIN-SECTION CHIPS.

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ABSTRACT.

Chief features of the apparatus described consist of metal parts designed to hold 20 to 25 rock chips securely in the plane of the lap surface for reduction to about ½ millimeter. Six to eight spotted chips are mounted on each of three, four-inch brass disks. These disks are screwed, chips down, to the under side of a three-armed spider of boiler plate. At the end of each arm is a downward projecting anchor pin and also an adjustable stop screw which is used to limit the thinness of the rock wafers. The anchor pins pass through holes slightly larger than themselves in a flange on the inside of the splash pan, the flange being practically at the level of the upper surface of the lap. Arrangement of the whole apparatus in a flat form, with grinding stresses and points of anchorage all practically in the same plane, eliminates all tendencies toward spring, or cramping of parts, and with an automatic carborundum feed the grinding proceeds with little or no attention from the operator.

In preparing thin sections of rocks for study in connection with the Honolulu water supply problem, a simple and effective method of machine-grinding a large number of chips with little or no attention from the operator has been devised. Since it is thought that the method might be of use to others it is here described briefly.

The work is done on a three-spindle, grinding lap, the bed of which consists of two lengths of six-inch, channel beam, spot-welded edge to edge. This is supported about ten inches above the table on four angle-iron legs and under it is a drive shaft, driven by a one-quarter H. P. motor at the rear, which is carried in ball bearings. The three ten-inch laps are mounted on vertical spindles which pass through the bed beam and are each provided with two ball bearings. The latter are clamped by means of bored housings to the top and bottom surfaces of the bed beam on spots trued with a fly cutter. The drive shaft runs 1220 R.P.M. and carries three pulleys consisting of belt leather clamped between metal discs by which power is transmitted to cast iron discs mounted at the lower ends of the vertical spindles, thus providing a means of adjusting the speed of the laps.

The drive shaft runs at 1220 R.P.M. and carries a small carborundum wheel at one end. If desired, a diamond saw could be mounted here, but the method of multiple grinding here described in considerable measure obviates the need for a diamond saw. The rough-grinding lap has been adjusted to a speed of about 1400 R.P.M. and the finishing laps run at about 1600 R.P.M.