ABSTRACTS OF RECENT GEOLOGICAL WORK ACCOMPLISHED OR ON PROGRESS

BY

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THESES COMPLETED

Banerjee, Anil K.: Ph.D., 1957; Structure and Petrology of the Oracle granite, Pinal County, Arizona.

Oracle granite, probably emplaced in older Precambrian time contains the relic pattern imposed on the Pinal schist by the Mazatzal orogeny. The "granite" of that time was a granodiorite. It is now a porphyritic quartz monzonite that varies unsystematically toward granodiorite and biotite granite. The trend of its principal Precambrian foliation is northeast-southwest and this is crossed by northwesterly-trending Precambrian foliation.

After the Mazatzal orogeny, peneplanation, and deposition of the younger Precambrian Apache group, a series of dikes was emplaced in the Oracle granite, beginning with coarse and medium grained diabase and ending with andesite and rhyolite. The earlier members of the sequence, including diabase, aplite, pegmatite, quartz and latite were emplaced when tensional stresses opened a series of northwest trending fractures. The tension seems to have been related to right lateral strike-slip along the Mogul fault zone, which forms the southern border of the granite.

In Jurassic or Cretaceous time the strike-slip on the Mogul fault was reversed; northeast-trending Pinal schist south of the fault was rotated counter-clockwise into partial parallelism with the fault, a transition zone north of the fault was likewise dragged and andesite and rhyolite dikes were emplaced in northeast-trending "feather fractures."

The structural and petrographic evidence suggests that metasomatism was important in the origin of the Precambrian ranodiorite, but the existence of some magma cannot be precluded. Likewise the evidence suggests that the potash metasomatism that changed the granodiorite to quartz monzonite may have taken place at the time of the later intense movements, that is, during Jurassic or Cretaceous time. However, an earlier age of potash introduction is not unlikely.

Bennett, Paul J.: M.S., 1957; The Geology and Mineralization of the Sedimentary Hills Area, Pima County, Arizona.

Mildly metamorphosed Cretaceous siltstones, arkoses and limey shales, and a small composite stock of granitic composition are the principal rocks exposed in the Sedimentary Hills area, which lies six miles west of Tucson, Arizona. About 2400 feet of sediments were measured and assigned to the Amole Arkose Formation. The beds dip to the south and strike northwesterly.

The stock is composed of two granitic facies. The northern and earlier part of the stock is a quartz monzonite which is mildly altered. The southern part of the intrusive is a granite prophyry which is altered to a greater degree and exhibits significant disseminations of chalcopyrite and pyrite. A quartz-pegmatite plug, probably a late phase of the intrusions, intrudes the quartz monzonite.

Structure in the area is dominated by a large thrust zone which strikes generally parallel to the bedding. Within the Sedimentary Hills area, normal faulting and drag folding are tributary to the thrusting.

Minor quantities of copper oxide minerals are frequent along large and small faults, and in the granite porphyry stock. Wide brick-red and brown gossans occur along the major thrust plane.

Brennan, Daniel J.: Ph.D., 1957; Geological reconnaissance of Cienega gap, Pima County, Arizona.

A new formation, the Pantano, of probable lower Miocene age is present. The Pantano formation consists of 13,762 feet of conglomerate, sandstone, and mudstones, with three andesite flows intercalated with the sediments. The presence of this extensive basin-fill deposit indicates that Basin-Range type structures were present in this part of Arizona as early as lower Miocene.

The Pantano formation has regional dip to the east, and is overlain by thrust blocks of older rocks and by younger sediments.

A simple thrust block of Precambrian granodiorite, with Bolsa quartzite deposited on it, is present in the east north central portion of the area. A large, complexly faulted block of undifferentiated Carboniferous rocks lies to the west.

In the central and south-central parts of the area there are imbricate thrust blocks of Bisbee(?) formation, quartz monzonite, and gneiss, lying over the Pantano. There was some minor alteration and mineralization along fault planes.

Presence of thrust sheets on the Pantano indicates that the last major disturbance in this region occurred after lower Miocene.

Late Tertiary and Quaternary deposits were not affected by the faulting. The area is now being actively eroded.

Burnette, Charles R.: M.S., 1957; Geology of the Middle canyon, Whetstone mountains, Cochise County, Arizona.

Middle Canyon, in the Whetstone Mountains southwest of Benson, Arizona, contains Paleozoic sedimentary rocks lying unconformably on the Precambrian Pinal schist. The sedimentary rocks dip to the southwest and are cut by two sets of high-angle faults, a major set with northeast trend and a minor set with northwest trend. The Pinal schist is intruded by Precambrian Whetstone granite and related pegmatite dikes.

The Paleozoic rocks mapped range in age from Cambrian to Pennsylvanian. Quartzites, conglomerates, and shales predominate in the lower part of the section. The upper Cambrian and younger rocks are chiefly limestones. A trilobite from the Abrigo limestone is identified by Stoyanow as a new species.

The Lonestar fluorite mine and one tungsten prospect contain the only known minerals of economic value. Mapping of the Lonestar mine shows localization of the fluorite vein along a shear zone in the Pinal schist.

Griswold, George B.: M.S., 1957; A study of the subsidence at the San Manuel mine, Tiger, Arizona.

A study was made of the surface subsidence at the San Manuel Mine with the aim of ascertaining the manner in which caving took place. The San Manuel Copper Corporation kept detailed records of the subsidence which were analyzed, and the writer mapped the location of the cracks which were developed during subsidence. A correlation was made between the drawing of ore and the surface expression of caving.

Block caving operations at San Manuel commenced early in 1956. During the middle of May 1956, evidence of subsidence began to appear, and by the end of the year, some 58 million cubic feet of ore had been withdrawn which caused a subsidence volume of more than 22 million cubic feet.

The present mining area is almost entirely covered by a variable thickness of Gila (?) conglomerate. The conglomerate did not appear to fragment in the same manner as did the underlying monzonites, and the surface therefore appeared to settle downward as a unit over the entire area being mined. The writer concluded that the caving proceeded vertically above each undercut area until the base of the conglomerate had been reached; as drawing continued the weight of the conglcmerate was shifted onto the area around each stope which caused shearing to take place. The formation of these shears caused the area influenced on the surface to be considerably larger than the area undercut.

Most of the subsidence was limited by a major escarpment surrounding the mining area. The location of the escarpment appeared to be dependent on the thickness of the conglcmerate; that is, the escarpment formed further out from the blocks in those areas where the thickness increased.

Cooley, Maurice E.: M.S., 1957; Geology of the Chinle formation in the Upper Little Colorado River Drainage Area, Arizona and New Mexico.

Detailed stratigraphic studies were made of the Chinle formation between Holbrook and St. Johns, on the Zuni Plateau, and on the northeast flank of the Zuni Mountains. Reconnaissance studies were made of the Moenkopi formation. In the upper Little Colorado River area a new member, the Mesa Redondo member of the Chinle is recognized. This report emphasizes the description of the many sandstone beds occurring in the Chinle formation. In the Zuni Mountains area the upper Moenkopi(?) sediments, previously believed to be typical of the Moenkopi formation in northeastern Arizona, are believed to represent later deposition, lying stratigraphically between the "typical" Moenkopi and the Chinle formation.

Major unconformities -- pre-Moenkopi, pre-upper Moenkopi(?), and pre-Chinle (pre-Shinarump) -- and several interformational unconformities are described, and their relations affecting sedimentation are discussed.

A geologic history of the Triassic is included which describes the interrelationships of the various depositional sequences and the unconformities to the changing physiographic and structural environments. Late Paleozoic to Late Triassic structural movements of the larger Mogollon and Uncompaghre highlands and the smaller granitic Holbrook ridge, Defiance uplift, and Zuni uplift, as indicated by the type and distribution of sediments, are discussed.

Jones, Richard D.: M.S., 1957; Geology of the Cerro Colorado mining district, Pima County, Arizona.

The Cerro Colorado mining district is located in southeastern Pima County, Arizona, 50 miles from Tucson.

Volcanic rocks and some sedimentary rocks of unknown age and correlation are exposed within the district. Quartz latite porphyry, as flows or shallow intrusives, and sandstone and arkose are the oldest rocks. These are overlain by a younger series, consisting of limestone, conglomerates, and andesite prophyry flows, breccias, and agglomerates.

Structures of the district include major east-west faults having strike-slip movement, northeast, northwest, and north-south faults, a northward trending syncline, and an arcuate arrangement of quartz prophyry dikes and sills. Dike rocks of miscellaneous other compositions are also present. The arcuate structure suggests the presence of an upward thrusting underlying intrusion, but the structure may be due to deflection of the dikes along major fault trends.

Mineralization in the district is confined to narrow quartz veins with infrequent sulphide mineralization. Total production, largely argentiferous tetrahedrite and galena, was $316,000.

Kidwai, Zamir U.: M.S., 1957; The relationship of ground water to alluvium in the Tucson area, Arizona.

The upper Santa Cruz basin in southern Arizona is typical of the Basin and Range province. Mountains surrounding the basin consist of many types of rocks ranging in age from Precambrian to Cenozoic. Operation of a variety of erosional and depositional processes have resulted in an alluvial complex of basin fill. The geologic factors controlling the formation of the valley fill determine the textural and structural relationships which control the occurrence and movement of ground water within the basin. The pattern of ground-water contours clearly shows the broad outlines of the geologic control of ground water.

A study of logs and samples of water wells was made in an attempt to show the extent to which they might be useful in relating known hydrologic properties of the basin to the geologic factors. It is shown that material usually described as "valley fill" consists of Recent alluvium of variable thickness along the main stream channels, an older, Pleistocene alluvial fill that underlies the basin to a probable depth of about 550 feet in most places, and Miocene(?) beds, probably correlative with the Pantano beds or the lower member of the Rillito beds, below this.

Study of well samples shows that the permeability of the older alluvium is roughly inversely proportional to the amount of Caliche in it, and also that some wells near the flood plains of main streams produce water from this older, rather than the Recent alluvium. Well samples are useful in correlating sediments between wells very near each other, but such correlations cannot be extended over large parts of the basin. A study of well logs is shown to be the cheapest and quickest method for studying the broad depositional and structural outlines of the basin.

McClymonds, Neal E.: M.S., 1957; The stratigraphy and structure of the Waterman Mountains, Pima County, Arizona.

The Waterman Mountains are located about 35 miles west of Tucson in Pima County, Arizona. In the Central and Eastern portion of the range the Pinal schist and Apache group are missing and a pre-Cambrian (?) granite underlies the Paleozoic sediments. The stratigraphy in the mountains includes the Cambrian Troy quartzite and Abrigo formation, the Devonian Martin formation, the Mississippian Escabrosa limestone, the Pennsylvanian Horquilla formation, the Pennsylvanian-Permian Andrada formation, the Permian Scherrer, Concha, and Rainvalley formations, and Cretaceous (?) strata. The sediments were deposited in a shallow, fairly stable basin. The Watermans were probably uplifted during the Laramide orogeny, when compressive stresses from the southwest pushed wedges of Paleozoic strata through the overlying Cretaceous (?) beds. The trends of the major faults within the mountains support the concept of a southwestern origin of compression with relatively older faults trending N. 45° W. and dipping southwestward. Relatively younger faults, probably tensional, trend N. 60° -70° E. and N. 85° W. Later Tertiary igneous intrusions are represented by rhyolite sills and dikes in the Cretaceous (?) sediments north of the range. The mineralization in the Watermans is probably related to the Tertiary igneous activity.

Smith, Riley S. Jr: Ph.D., 1957; A study of the Chinle-Shinarump beds in the Leupp-Holbrook area, Arizona.

The Shinarump and Chinle beds were investigated in the Leupp-Holbrook area of northeastern Arizona. Cross-stratification trends and cobble studies suggest a southeastern source for the material. A southwestern source direction is also postulated by the presence of Kaibab fossils, gray quartzite, and granite cobbles. The possibility exists that the granite and quartzite are from the Bradshaw Mountains near Prescott.

Coarse clastic facies in the Lower member of the Chinle show a decrease in quantity and grain size toward the northwest, correlating with the Shinarump findings. Another notable change is the thinning out and disappearance of some of the cliff-forming Upper Chinle units as they are traced southeastward from Leupp to Smith Butte.

The most useful feature for stratigraphic control in the area is a resistant, cliff-forming, porcellanite bed, found at the base of the Owl Rock, the uppermost member of the Chinle formation.

Some of the "limestones" of the Chinle formation in the area were found to be true limestones, but others are marlstones and porcellanites. The lime is believed to have been precipitated by evaporation from shallow, flood plain, lake waters. The soluble salts may have been flushed out by waters from associated streams during flood stage. The silica responsible for the highly siliceous nature of certain Owl Rock units is believed to have been released by the decomposition of reworked volcanic ash and its conversion into montmorillonite. Silica carried by groundwater possibly enriched the already siliceous rocks. The chert is secondary.

Some substantiating evidence is offered for the concept of the Shinarump as a regressive, blanket deposit, and the Chinle as transgressive, upward building deposit.

St. Clair, Charles S.: M.S., 1957; Geological Reconnaissance of the Agua Fria River area, Central Arizona.

The Agua Fria River area is part of a mass of crystalline Precambrian rocks covered, in several places, by Cenozoic volcanic and sedimentary rocks. The volcanic rocks and the sediments are largely the products of eruptions in middle (?) Cenozoic time.

The rocks are sequences of volcanic flows of basaltic and andesitic composition, conglomerates, and interlayered tuffaceous sandstones. In places the cover of Cenozoic rocks was apparently in excess of 2000 feet, but erosion has removed much of this material.

Pleistocene or Recent gravels, terrace deposits, and dissected alluvial fans are unconformable on the Cenozoic rocks throughout the area.

The Cenozoic rocks are nearly horizontal; some have a slight dip to the northeast. At the southern end of the area are broad, open anticlines and snyclines which are thought to be marginal features of a major shear zone which lies to the south of the area.

The source of all the volcanic debris is unknown. An andesite plug and three basaltic dikes in the southern part of the area served as a source for at least some of the material.

Some of the Cenozoic deposits seem to have been deposited on an erosion surface that had hundreds of feet of local relief.

Little is known of the time relationships of the various Cenozoic rocks in the area for none has yielded datable fossils. By lithologic and structural analogy, the Cenozoic rocks of the Agua Fria River area have been assigned tentatively to middle and/or upper Miocene and lower Pliocene.

Sulik, John F.: M.S., 1957; Stratigraphy and structure of the Montosa Canyon area, Santa Cruz County, Arizona.

Sedimentary rocks of Pennsylvanian, Permian and Cretaceous age are present in the Montosa Canyon area and are the only sedimentary units exposed on the southwest flank of the Santa Rita Mountains. The major portion of the conspicuous limestone hogback of the area is composed of the Permian Scherrer, Concha and Rainvalley formations. The late Paleozoic rocks have been thrust over a thick sequence of undifferentiated Cretaceous sediments which are intruded on the east by quartz monzonite and latite porphyry. The igneous units are of probable Laramide age.

The Paleozoic rocks are in imbricate thrust plates trending generally north-south. A younger set of tear faults trending generally east-west cuts the shear faults but has not been found to cut the imbricate thrust plates.

Van Horn, William L.: M.S., 1957; Late Cenozoic beds in the Upper Safford Valley, Graham County, Arizona.

A sequence of poorly to medium-well consolidated sediments occur in the upper Safford Valley. They consist of lacustrine deposits, herein called the Solomonsville beds, overlain by terrace gravels and alluvium.

On the basis of contained fossils the upper Solomonsville beds are post-early Kansan in age. They are equivalent to a part of the Gila conglomerate. The sediments of the Solomonsville beds were derived from a local source area. The faulting which produced the basin in which the Solomonsville beds were deposited was prior to late Pliocene.

The terrace gravels are Pleistocene in age and are related to moist and arid cycles during the Pleistocene.

Quality of the ground water derived from the Solomonsville beds is related to the soluble salts contained in these beds. These soluble salts were deposited originally with the sediments or may be of post-depositional origin.

Webb, Robert T.: M.S., 1957; Petrography, structure, aand mineralization of the Meadow Creek area, Chelan County, Washington.

The Meadow Creek mining district, with mainly copper, gold and silver mineralization, is located in the northern Cascade Mountains of north central Washington. The rocks present represent in part a thick sequence of eugeosynclinal sediments and volcanics which have undergone regional metamorphism. Included in the area are both igneous and metamorphic rocks. Those of metamorphic origin are gneissic granodiorites, quartz-feldspar gneisses, amphibolites, biotite-garnet schists, actino-tremolite schists, and quartz-feldspar replacement dikes. Irregular bodies of quartz diorite have intruded the metamorphics and antedate numerous andesite, basalt porphyry and dacite porphyry dikes that lace the area.

Structurally the metamorphics have regional foliation trending generally N 20 - 30° W and dip vertically. These rocks have been subjected to mesozonal kinematic metamorphic conditions with local sodium and potassium metasomatism forming quartz-feldspar replacement dikes. Some of the quartz-feldspar gneisses represent igneous material that was introduced subsequent to the peak of thermal activity. Stress was active for a time after the thermal activity causing cataclastic structures to be formed.

Major east-west mineralized shear zones and smaller northeast and northwest striking zones transect the rocks of the area. These zones contain massive sulfide veins and stringers formed as a result of both open space filling and replacement. Mineralization, a function of hydrothermal introduction, established a mineral assemblage indicative of hypothermal conditions. The occurrence of open spaces with hypothermal metallization is not the normal case, but is strongly suggested by the association of euhedral quartz crystals in the gangue. The sequency of mineralization is quartz, arsenopyrite, pyrrhotite, chalcopyrite, sphalerite, marcasite. Hydrothermal alteration near mineralized zones has formed abundant clay and sericite.

Small post-mineralization faults cut the shear zones causing minor displacements. Pleistocene and Recent glaciation scoured and modified the terrain and covered much of the area with drift.

Weidner, Melvin I.: M.S., 1957; Geology of the Beacon Hill-Colossal Cave area, Pima County, Arizona.

The Beacon Hill-Colossal Cave area consists of a thrust of early Paleozoic sediments over a quartz monzonite (erroneously named the Rincon granite) of either Late Cretaceous or Early Tertiary age. The sedimentary rocks include the Cambrian Bolsa quartzite and Abrige formation, Mississippian Escabrosa limestone, Tertiary(?) sandstone, Tertiary(?) red breccia, and Tertiary(?) and Quaternary alluvium; the igneous rocks include the Rincon granite, a diabase dike-sill complex of Tertiary(?) age, and an altered peridotite located in an apophysis of the diabase. The structure (faults, folds, and joints) of the area is associated with the thrust.

Whitney, Richard L.: M.S., 1957; Stratigraphy and structure of the northeastern part of the Tucson mountains.

The northeastern foothills of the Tucson Mountains include a number of klippen of Paleozoic sediments, remnants of a thrust sheet which over-rode Cretaceous sedimentary and igneous rocks during a period of intense compressive deformation that occurred sometime between late Cretaceous and Miocene(?). A period of high angle faulting preceded and another followed the emplacement of the thrust sheet.

No stratigraphic sequence could be established, but rocks ranging in age from Devonian to Permian were identified in the various klippen. A definite conformity exists in the attitudes of the major Paleozoic blocks, as their strikes fall into a general east-west alignment.

Several Laramide intrusive bodies and volcanics of Tertiary and Cretaceous(?) age are present in this area.

Acker, Clement J.: M.S., 1958; Geologic Interpretations of a siliceous breccia in the Colossal Cave area, Pima County, Arizona.

In the Colossal Cave area, Pima County, Arizona, massive blocks of Paleozoic sedimentary rocks have been thrust from a southerly direction over an irregular surface of Rincon Valley granite of Laramide age. The Paleozoic rocks involved in the thrusting are the Bolsa quartzite, Abrigo formation, Martin limestone, Escabrosa limestone, Horquilla limestone, and Andrada formation. The Pantano formation (Miocene ?) is also present under the thrust sheet.

The thrusting is of an imbricate nature with slippage mainly taking place along incompetent rock units. Large folds occur in the Escabrosa limestone and Horquilla limestone.

A siliceous breccia is associated with thrust planes in the area. The competent units of the Paleozoic sediments were fractured and brecciated along the thrust planes. Solutions dissolved part of the silica and hematite from the Bolsa quartzite and deposited it in the fractured and brecciated zones.

Bissett, David H.: M.S., 1958; A survey of hydrothermal uranium occurrences in southwestern Arizona.

Five hydrothermal uranium prospects occurring in the Basin and Range Province of southeastern Arizona were studied, and 134 additional prospects were located on a regional map of the district. From data provided by this study, it was found that hydrothermal uranium is usually deposited as open-space filling or "tight" fracture replacement in faulted, sheared, or brecciated ground. This deposition took place most typically within acid intrusive rocks close to their contacts with sedimentary or metamorphic wall-rocks, or within the wall rock closely adjoining the intrusive contact.

Acidic intrusives of Laramide age are believed to be most favorable. Ore controls are primarily structural, with shearing, shear-tension intersection, and cross-fracturing predominant. Brecciation along anticlinal crests is an important control at two of the occurrences.

At one of the prospects, extensive supergene enrichment was noted. Weathering and leaching of surface outcrops is probably a significant factor at all of the occurrences studied.

Browne, Jonathan F.: M.S., 1958; The geology of the Cuprite Mine area, Pima County, Arizona.

The Cuprite Mine area is located in southeastern Pima County, Arizona, approximately 28 miles southeast of Tucson.

Thrusting from the southeast has produced a wide expanse of breccia between Paleozoic and Cretaceous sediments.

Northwest, northeast, and east-west tear faults have offset the thrust sheet.

The present arcuate trend of the sediments and breccia zone around the granite intrusive is ascribed to doming of the thrust sheet by the intrusive.

Other intrusive rocks in the area are diorite, alaskite, and quartz porphyry. Gneiss is found at the northern edge of the area.

Minor pyrometasomatic copper mineralization occurs throughout the area.

Colby, Robert E.: M.S, 1958; Stratigraphy and structure of the Recreation redbeds, Tucson Mountain Park, Arizona.

The Recreation redbeds present a problem in complex Cretaceous(?) stratigraphy in an area which has been deformed by faulting and minor folding. The original Recreation redbeds formation consisted of only a sandstone-siltstone member. It has now been expanded to include a volcanic conglomerate member and a tuff member. These new members were originally part of another formation.

The Recreation redbeds-Amole arkose relationship was found to be conformable and gradational through the volcanic members of the redbeds.

Two thrust faults border the area. A large block of Recreation redbeds moved eastward, onto the Amole arkose, along the eastern one. The western fault brought Amole arkose up on to the middle part of the redbeds.

Andesite and basalt intrusives apparently used the faults as channels, where they intruded and deformed the sediments. The unusual folded structure on southern Brown Mountain is possibly due to the lifting action of these intrusions.

The Amole granite forms the northern intrusive border of the Recreation redbeds. Latite dikes intrude the formation along west-northwest fractures. Carbonate material has been introduced into local permeable parts of the formation. Mineralization is present as limonite and quartz in north-northwest fractures.

Havenor, Kay C.: M.S., 1958; Pennsylvanian framework of sedimentation in Arizona.

A historical review is presented to evaluate and correlate the past and present nomenclature of the Pennsylvanian system of Arizona and adjacent areas. The lithology and age relationships of the formations present at the various localities within each of the four quarters of Arizona are summarized with respect to the stratigraphic and tectonic relationships of each division and its adjacent areas.

The present distribution and lithology of the Pennsylvanian and subjacent rocks indicates that during latest Mississippian and earliest Pennsylvanian time nearly all of Arizona was a positive area which had been epeirogenetically uplifted during Late Mississippian time. Throughout wide areas of Arizona a regolith and karst topography developed on the broadly exposed Mississippian limestones.

No rocks of Morrowan age are known in Arizona. By Desmoinesian time a major portion of eastern and southern Arizona was completely inundated by seas from Cordilleran and Sonoran geosynclines. During Virgilian time the seas reached their maximum extent, covering all of Arizona except the Defiance Uplift which was a positive feature throughout Pennsylvanian time.

Heindl, Leopold A.: Ph.D., 1958; Cenozoic alluvial deposits of the Upper Gila River area, New Mexico and Arizona.

Cenozoic deposits in intermontane basins in the upper Gila River basin have been collectively included in the Gila conglomerate of Gilbert and Ransome. Re-examination of type-section areas shows that the term is unsatisfactory because it includes a substantial proportion of deposits other than conglomerates; it suggests that deposits in separate basins are identical; its use masks sequences of alluvial deposits within individual basins and relationships of deposits between basins; and it oversimplifies a complex Cenozoic history. It is suggested that the term Gila conglomerate be abandoned. The deposits, in the many basins, which heretofore may have been included in the Gila conglomerate, can be separated into two major divisions which may in turn be subdivided into mappable rock units.

In each structural trough the upper units are characterized by: (1) Truncation by the highest pediment surfaces; (2) depositional or normal-fault contact with adjacent mountain areas whose composition the deposits reflect; (3) size-gradation relationships that suggest deposition within the boundaries of the present structural troughs; and (4) lack of mineralization. Limited fossil evidence suggests that deposition occurred during Pliocene to Pleistocene (Kansan) time.

The lower units crop out in areas of deep dissection or structural uplift. They may be in fault contact with the upper units, underlie them unconformably, or grade into them. The lower units are characterized by: (1) Texture and composition that suggest deposition in basins other than those reflected by the present topography; (2) thrusting or normal faulting more complex than that associated with the upper units; (3) local mineralization; and (4) shallow intrusion. Limited fossil evidence suggests a Miocene age for some of the older of the lower units.

The alluvial deposits in individual basins in this area are amenable to stratigraphic analysis by standard procedures for describing rock units. Correlations within or between basins should be on the basis of proper fossil or stratigraphic evidence and should be limited to the particular units involved and not expanded to include all the alluvial deposits in the areas concerned.

Heyman, Arthur M.: M.S., 1958; Geology of the Peach-Elgin copper deposit, Helvetia district, Arizona.

The Peach-Elgin prospect, located in the Helvetia mining district, Pima County, Arizona, is a low-grade deposit of disseminated copper mineralization in silicated limestone. Rocks consist of coarse-grained granite, Tertiary(?) quartz monzonite porphyry, andesite prophyry, Horquilla formation, Concha limestone, and Scherrer quartzite. The Horquilla limestone and siltstones are selectively metamorphosed to garnet-diopside rock, garnet rock, tremolite siltstone, and marble, the mineral suites reflecting the original composition of the beds.

The deposit lies in an outlier of the upper plate of the north-south trending Helvetia thrust fault. The outlier lies one and one-half miles west of its pre-thrust position and is underlain by granite. Several similar trending thrusts and the Helvetia tear fault make up the major structures of the district. In the prospect area two faults, imbricate to the Helvetia thrust, move Concha above Horquilla and Horquilla above Scherrer. Several cross faults occur, including the Tip Top fault, which have pre-thrust, post-thrust, and post-mineralization ages. The Horquilla of the Peach hill appears to be folded into a broad syncline.

Copper mineralization of the prospect is largely confined to the silicated rocks and is controlled in part by bed composition. The aluminum-deficient diopside beds are more favorable than the aluminum-rich garnet beds. Predominant ore minerals are chalcopyrite, chalcocite, chrysocolla, "copper pitch," and bornite with associated pyrite, magnetite and iron oxides. They occur as disseminated grains, replacement veinlets, and in quartz-calcite veins. Ore is localized by the thrust faults, the Tip Top fault, and fault intersections. Depth of oxidation is controlled by topography, averaging 100 feet on steep hills and 50 feet in flatter areas. Bed composition also controls oxidation, mineralization in the garnet beds being strongly oxidized at all depths explored. Enrichment is spotty and is probably restricted to zones of complete silication. Oxidized capping occurs over parts of the Peach-Elgin area.

Mineralization in the district is related to the quartz monzonite porphyry. Intrusion, silication, movement of the Helvetia thrust and of the tear fault, and mineralization occurred nearly contemporaneously.

Kerns, John R.: M.S., 1958; Geology of the Agua Verde Hills, Pima County, Arizona.

The Agua Verde Hills are part of an imbricate sheet that has been thrust over Pantano formation sediments of Miocene(?) age. Portions of the Bolsa, Horquilla, and Andrada formations comprise the thrust sheet. Intense folding formed anticlines with steep or overturned northern limbs and gently dipping southern limbs. The direction of movement as interpreted from the fold axes and dips of the fold flanks is from a southerly direction. A quartz monzonite stock of Laramide age crops out along the northern edge of the area and is the probable cause of the termination of thrusting movement. Nearly pure quartz was intruded along the thrust plane and other zones of weakness during the thrusting. After the interval of siliceous intrusion, basic intrusives came in along zones of weakness during the thrusting and show some shearing effects from the faulting. Later tension faulting has offset some of the fold axes and uplifted the Pantano formation in the southern part of the area.

Kinnison, John E.: M.S., 1958; Geology and ore deposits of the southern section of the Amole Mining District, Tucson Mountains, Pima County, Arizona.

The southern section of the Amole Mining District was once covered by the Paleozoic strata common to southern Arizona. The Mesozoic strata consist of the dominantly clastic Amole group which, beginning with a basal conglomerate, is subdivided into four formations. The lower two are of Lower Cretaceous age, and the upper two are Upper Cretaceous or early Tertiary. These formations were intensely folded into a synclinorium with local thrust faulting during the Laramide revolution, and subsequently planed to a gentle erosion surface. The Tertiary formations are assigned by inference to the middle or late Tertiary, and begin with the Tucson Mountain chaos. This is a tabular unit about 200 feet thick composed of fragments of pre-Laramide rocks ranging in size up to 350 feet, and is postulated to be a sedimentary deposit resulting from combined fault action and landslide. Conformably above this formation is a layered sequence of volcanic and sedimentary rocks, which is divisible into a number of formations. These rocks were tilted northeasterly and broken by numerous high-angle faults, and mineralized by ore solutions with a high silica content. The youngest rocks are conglomerates, local (?) lake beds, basalt flows, and recent alluvium.

Layton, Donald W.: M.S., 1958; Stratigraphy and structure of the Southwestern Foothills of the Rincon Mountains, Pima County, Arizona.

The Southwestern Foothills are topographic outliers of the Rincon Mountains. These foothills are part of an imbricate thrust sheet containing rocks of late Paleozoic and Tertiary age. Portions of the Horquilla limestone, Andrada, Scherrer, and Pantano formations are exposed. Folds in the sedimentary rocks trend east-west. Tension faults trend north-south and east-west. Shear faults have a general northeast-southwest trend and a northwest-southeast trend. The thrusting from the south is dated as post-Pantano. An autochthonous quartz-monzonite mass of late-Laramide age crops out along the northern edge of the thrust sheet. Basic intrusives occur in some of the thrust zones.

Lutton, Richard J.: M.S., 1958; Some structural features in southern Arizona.

The complication of Laramide fold structure in southern Arizona, as revealed on aerial photographs, may be in part the effect in cover rocks of left-lateral wrench faulting along a basement geosuture. Bedding trends reveal segments having a reverse S pattern. The center of the S is often northwest to north-northeast and it passes at both ends into steeper west-northwest bedding. Mapping in the Sawmill Canyon area disclosed at the surface what is considered to be one of the basement wrenches.

This area gives some evidence for the history of Laramide deformation visualized from the bedding attitudes: (1) north-northwest folding; (2) reactivation of old west-northwest wrench faults; (3) dragging and buckling of cover folds into the west-northwest trend; (4) destruction of west-northwest folds by steep, bedding faults over basement wrench faults; and (5) intrusion of stocks into cover over wrenches.

Post-Laramide(?) deformation exemplified by the Santa Rita-Empire-Whetstone Mountains area is believed by the author to be also principally dependent on the wrench faults in the basement. In this area detached cover rocks appear to have been thrust diversely in response to the crowding of underlying blocks adjusting along wrench faults.

The reason for the lack of obvious throughgoing wrench faults is possibly that at the surface such structures are masked by parallel, related thrusts, or branch into north-northwest thrusts.

MacKallor, Jules A.: M.S., 1958; Geology of the western part of the Cobabi Mining District, Pima County, Arizona.

An area of fifty square miles midway between Tucson and Ajo, Arizona, has been mapped on a scale of one inch to two miles. Exclusive of Quaternary alluvium and talus, igneous rocks constitute 95 percent of the bedrock and sedimentary rocks constitute five percent. Many of the formations in this area closely resemble formations in the Tucson Mountains but have little or no resemblance to the rocks in the Ajo area.

Extrusive rocks consist of flows of intermediate to basic composition, and they have been divided into five formations. The total thickness is calculated to be about 10,000 feet. The thickest flows are Late Cretaceous, and they were eroded and faulted before the Tertiary flows were extruded. A volcanic conglomerate composed of volcanic ejecta is the only evidence for explosive volcanic activity in the area. The Late Cretaceous volcanics have been intruded by acidic stocks and dikes.

The oldest sedimentary formation in the area is a thick unit of red shale containing thin beds of pebble conglomerate and sandstone. Beds of Tertiary conglomerate and gravel lie underneath the youngest flows.

A period of folding and thrust faulting was followed by a period of block faulting. A pattern of N-S, NW-SE, and E-W faults was developed at the time of block faulting. Many of these faults served as paths for the intrusion of felsite dikes and quartz veins. Faulting continued until after the extrusion of the youngest flows in the area.

Quartz veins and stringers in andesite and granite contain gold, silver, copper, and lead minerals. Attempts to mine the veins have not been very successful because the veins are narrow and of comparatively low grade.

McLehaney, James D. Jr.: M.S., Mining Engineering, 1958; A study of subsidence due to mining by block caving, San Manuel mine, Pinal County, Arizona.

The problem of subsidence attends many mining ventures but is particularly acute with respect to large-scale caving operations. A study of subsidence was undertaken at the San Manuel mine, Pinal County, Arizona, to determine the extent and mode of subsidence.

A block caving method of exploiting the copper deposit was begun in early 1956. Detailed studies of the draw and subsidence have been maintained by the San Manual Copper Corporation and the United States Bureau of Mines. By the end of this period of study, January 1958, some 117,158,000 cubic feet of subsidence was produced by a removal of 176,017,000 cubic feet of material.

The geologic environment of the area is comprised of a zone of quartz monzonite and monzonite porphyry almost entirely overlain by a variable thickness of conglomerate capping. The two distinctly different rock types, the porphyry and the conglomerate, have fractured differently and the surface has settled en-masse with the greatest amount of subsidence and movement toward the center of influence of mining.

The writer concludes that fracturing associated with subsurface caving occurs upward from the undercut blocks and enlarges toward the base of the conglomerate. The conglomerate fractures along a high angle of break. Major escarpments form in thicker portions of the conglomerate, whereas minor subsidence escarpments form where the conglomerate is thinner or absent. The conglomerate capping fails in tension from a beam or cantilever action which ensues as draw removes support from the capping. Escarpments form along more prominent breaks and are modified as to their location and magnitude in areas where planes of weakness are present.

Ultimate angles of draw are dependent upon structural and physical features such as the height of the porphyry column, the variable thickness of the conglomerate, the strength of the rock masses, and intensity and orientation of planes of weakness.

Moore, Richard T.: M.S., 1958; Geology of Northwestern Mohave County, Arizona.

An area of approximately 4,200 square miles in northwestern Mohave County Arizona was mapped at a scale of one inch equals two miles. This region is of both structural and stratigraphic interest because it contains the boundary zone between the two major physiographic provinces of the southwestern United States: (1) the Basin-and-Range Province, and (2) the Colorado Plateau Province. Consistent with observations made in other areas is the fact that the Colorado Plateau Province is structurally lower and stratigraphically higher than the adjoining Basin-and-Range Province.

Precambrian metamorphic rocks, igneous rocks of Precambrian and Cenozoic age, and sediments ranging in age from Cambrian to Recent were mapped. Paleozoic sedimentary rocks in the Plateau portion of the mapped area are approximately 5,500 feet thick and in the Basin-and-Range portion 6,500 feet thick. Most of the Mesozoic formations have been removed by erosion. Cenozoic sediments, consisting of basin fill material, are restricted to the Basin-and-Range portion of the area.

The stability of the basement complex under the Plateau is demonstrated by the slight deformation the post-Precambrian sediments there have undergone. The instability of the basement complex under the Basin Ranges is demonstrated by the late Mesozoic to Recent orogeny in that area and it is suggested that the areal extent of the orogeny is controlled by ancient crustal weaknesses.

Peirce, Frederick L.: Ph.D., 1958; Structure and petrography of part of the Santa Catalina Mountains.

Field relationships in the Santa Catalina Mountains suggest that the so-called Tertiary intrusion of granite was not an intrusion in the common sense of the word, but rather a remobilization of a Precambrian granite during Tertiary(?) time. This granite has a gneissic structure, and crops out in the southwestern half of the Santa Catalina Mountains. The gneissic granite is overlain by a sequence of sediments which have undergone an upper medium grade (amphibolite facies) synkinematic metamorphism. Field observations indicate that the metamorphosed rocks represent Precambrian and Paleozoic sediments; the same stratigraphic sequence which overlies the relatively unmetamorphosed Precambrian granite in the northern part of the mapped area. The gneissic granite invades the metamorphosed sediments, locally, either in areas of highest mobilization, or by replacement of the country rock.

The sediments have been only slightly metamorphosed where they overlie the relatively unmetamorphosed Precambrian granite on the northeastern flank of the mountain, but where they overlie the gneissic granite along the crest of the Santa Catalina Mountains, they have been affected by the upper medium grade metamorphism.

The orogeny apparently took place during Laramide time, but as sediments younger than Permian were not recognized in the area of this study, the Laramide date for the orogeny is only supposition, although it is based partly upon the observations of other geologic investigators.

Prior to the Laramide orogeny the Precambrian granite was apparently covered by at least 15,000 feet of sediments. A supply of heat from an unknown source and compressional stresses apparently initiated the upward movement of the solid Precambrian rock. The heat must have been great enough to make the granite somewhat plastic, and as it pushed upward foliation developed. Schistosity also developed in the sediments above the upward moving granite apparently as the result of slippage along bedding planes. During the final stages of this orogeny the heat must have decreased, as the last stages of movement were accompanied by cataclastic action, rather than a further recrystallization of the minerals.

The orogeny was accompanied by the emplacement, at least in part as an igneous mass, of the Leatherwood quartz diorite, which was followed by the emplacement of the Catalina granite. Some of the border phases of the Catalina granite apparently represent replacement of sediments; however, that some of the granite was igneous is shown by the chilled borders of dikes of the Catalina granite that cut the Leatherwood quartz diorite. Pegmatities, emplaced during the later stages of deformation, appear to have formed by replacement of the country rock along zones of structural weakness, particularly near the contact between the gneissic granite and the metamorphosed sediments. Although faulting was perhaps continuous in this area, it is evident that much of it has taken place during the last stages of the deformation described above, or after the deformation had ceased. Much of the late faulting that can be observed may have taken place along old fault lines.

The following discussion describes the effects of the metamorphism upon the Precambrian and Paleozoic sediments and also the effects and relationships of the metamorphism to the granitic rocks. A summary of the structural and metamorphic history in the Santa Catalina Mountains based upon the observations made during this study is included.

Titley, Spencer R.: Ph.D., 1958; Silication as an ore control,
Linchburg Mine, Socorro County, New Mexico.
(See paper in this volume.)

Sulfide minerals occur in silicated limestone beds in the Linchburg mine locality. Principal control can be related to feeding faults and fractures through which the hydrothermal fluids were introduced into certain favorable limestone beds in the Kelly formation. Zoning of both silicate and sulfide minerals was observed in which certain sulfide minerals could consistently be correlated with certain minerals of the silicate suite. The most persistent favorability noted was that of sphalerite for garnet. This favorability is evidenced by confinement of sphalerite to areas characterized by garnet and by a possible crystallographic control exerted by garnet.

It is suggested that a reaction gradient was the most influential control upon deposition of all hydrothermal minerals. This gradient may have been only slightly influenced by temperature change but was strongly influenced by pH or Eh changes which it is shown could have existed.

Development of silicate zones is explained from the standpoint of ion behavior. Development of sulfide minerals is explained upon the basis of cited experimental work. It is suggested that sulfur, carried into the limestone horizons as a complexer of metal cations, reacted with early-formed silicates, in an acidic environment, altering them to amphiboles and chlorites. These reactions polymerized the complexes resulting in deposition of sulfides.

Wood, Paul A.: M.S., 1958; A Miocene camel from Wellton,
Yuma County, Arizona.

A fossil locality six miles northeast of Wellton in southwestern Arizona contains fragmentary remains of a new Arikareean (?) camel, Stenomylus arizonensis sp. nov., together with heteromyoid rodent teeth and an unidentified larger camel.

Stenomylus arizonensis sp. nov. is very similar to S. hitchcocki Loomis 1910. However, S. arizonensis has more compressed M_3 and M_2 and larger M^3 and M^2.

No evidence was found to support Loomis' theory that Stenomylus is an upland form.

Lack of sufficient geological information prevents any regional correlations; however, there are some indications that widespread equivalent Miocene formations may be present in adjacent parts of the Southwest.

THESIS WORK IN PROGRESS

Akers, J. P.: The Chinle-Shinarump of the Paria plateau area of northern Arizona.

Bryant, Donald G.: Intrusive breccias and ore.
This study attempts to develop an integrated theory of origin and localization of intrusive breccias to facilitate their use as ore guides. A detailed study of intrusive breccias of the Warren mining district, Bisbee, will be included.

Bryner, Leonid: The geology of the Southern Comobabi mountains and the Ko Vaya hills, Pima County, Arizona.
A study of approximately 80 square miles underlain primarily by volcanic and intrusive igneous rocks.

Burdick, Clifford L.: An integration of the geology of the Tucson perimeter.
This study seeks to integrate the disconnected studies already made of the ranges surrounding Tucson, by geological reconnaissance of critical areas and compilation of existing maps.

Burroughs, Richard L.: Geology of the Foy Ridge area, Twin Buttes, Arizona.

Chambers, Arthur E.: Geology and ore deposits of the Bay Horse quadrangle, Custer County, Idaho.
Detailed study of the geology and mineral deposits. Includes stratigraphy, structure and economic geology. To be published by Idaho Bureau of Mines.

Dausinger, N.E.: Guides to ore deposits at Suaqui Grande, Sonora, Mexico.
Geology of this region with emphasis on altered outcrops and gossans as guides to copper mineralization.

Fergusson, William B.: Cretaceous stratigraphy of Cienega Valley, Pima County, Arizona.

Fries, Carl Jr.: Areal geology of western Morelos and adjacent areas of central Mexico.
The region proposed for study was not previously mapped geologically. The purpose of this study has been to determine the rock units present, the periods of folding and faulting that affected these units, and the relationship between the pre-Pliocene tectonic history and the late Pliocene-Pleistocene east-west belt of volcanism that crosses Mexico at about the 19th parallel of latitude. Other problems consisted of defining the thicknesses, lithology, and facies changes of the Cretaceous rocks, the type and intensity of folding of these rocks, the reasons for deposition of irregularly distributed thick terrestrial deposits of early Tertiary age, the broad relationships between the tectonic history and the mineral deposits of the region, and the cause (among others) of the formation of the present interior drainage basin in which Mexico City is located.

Gray, Robert S.: Stratigraphic framework of the pre-Devonian Paleozoic of Arizona.
Study consists of assembling data on the early Paleozoic of Arizona, together with the measurement of critical rock sections, analyses of samples, and, finally, collation of these data to determine history of sedimentation in Arizona during this time.

Hammer, Donald F.: Geology and ore deposits of the Jackrabbit area, Pinal County, Arizona.
The Jackrabbit area contains Younger Precambrian and Paleozoic sediments which have been greatly deformed and have suffered magmatic intrusion. Mineral deposition has occurred at contacts between intrusive and limestone, producing several precious-metal deposits. The study attempts to resolve the structural history and determine the nature of ore controls.

Hopfenbeck, Theodore H.: Petrographic study of the Poco Rico ore body, Yauricocha, Peru.
Mineralogy and paragenesis, chemical environment, and associated silicate alteration of the Poco Rico monzonite intrusion will be studied.

Howell, Paul W.: Origin and relationships of bleaching clay deposits in east central Arizona.
This problem also relates to history of geological events in uplift of the southern edge of the Colorado plateau.

LeMone, David: Stratigraphy of Devonian beds in southeastern Arizona.
Correlation of Devonian formations over a large area by stratigraphic and paleontologic studies, and distribution of Devonian seas.

Mackison, Dorothy L.: Fusulinids from the Earp formation, Gunnison Hills, Cochise County, Arizona.
The study will include identification of the fusulinid fauna and determination of ages represented.

McCullough, Edgar J.: A structural study of the Pusch ridge - Romero Canyon area, Santa Catalina Mountains, Arizona.
Relating structures in these schists and gneisses to the broader study being carried on of the geology of the Santa Catalina Mountains.

Michel, Fred A. Jr.: Geology of the King mine, Helvetia, Arizona.
Study of structural controls and physical-chemical environments during mineralization.

Miller, Donald E.: Insoluable residues of the Mississippian system.
An attempt to correlate Mississippian strata through diagnostic insoluble residues as well as by more conventional methods.

Olson, Harry J.: The geology of the Glove mine, Santa Cruz County, Arizona.
General geology, ore environment, and ore controls of recently-distinguished wulfenite locality.

Peirce, H. Wesley: Stratigraphy of the DeChelly sandstone of Arizona and Utah.
A detailed field and laboratory study.

Purdom, William B.: Geology of La Minera Occidental Bosch, S.A., and the Coto Francisco, Pinar del Rio, Cuba.

Raabe, Robert G.: Structure and petrography of the Bullock Canyon-Buehman Canyon area, Pima County, Arizona.

Ryno, Creighton G.: Magnetometer survey of parts of the Santa Cruz Valley near Tucson, Arizona.

Investigation of concealed pre-alluvium bedrock structures in an attempt to correlate them with formations and structures of the surrounding mountains.

Samii, Cyrus: Magnetic survey of Twin Peaks area, Pima County, Arizona.

An attempt to determine bedrock structures beneath recent sediments.

Sell, James D.: Bedding replacement deposit of the Magma mine, Superior, Arizona.

The problem is to find the controls which guided the ore in its replacement of a lower section of the Martin limestone of Devonian age.

Shride, Andrew F.: Geology of the McFadden Peak quadrangle and adjacent areas, Arizona.

A detailed study of stratigraphy, structure, igneous geology and associated metamorphisn of rocks in an area underlain dominantly by the younger Precambrian formations of central Arizona. The mineral resource potential of the area is to be appraised with particular emphasis on the origin and distribution of chrysotile asbestos deposits.

Studebaker, Irving G.: Geology, structure, and stratigraphy of an area south of San Xavier, Pima County, Arizona.

Thomas, George C.: The framework of Mississippian sedimentation in Arizona.

The problem consists of determining areas of sedimentation, thickness and lithology of the system, and the distribution of land masses during the Mississippian period in Arizona.

Walker, Giles E.: A study of flow structures in intrusive rocks of the southern California Batholith near Bonsall, California.

The problem deals primarily with the mechanics of intrusion of units of this batholith as revealed by its internal structure.

Wargo, Joseph G.: Geology of the Schoolhouse Mountain quadrangle, Grant County, New Mexico.

General geology, structure and petrography are being studied. Attempts are being made to correlate volcanic flows and tuffs by means of geophysical and geochemical methods (magnetic susceptibility measurements and determination of characteristic refractive indices of fused rock samples).

Williams, Sydney A.: The series chlorastrolite-X and related Keweenawan minerals.

Involving the complete description of a new mineral "X" and synthesis of members of this series. Study of the occurrence of these and other related secondary minerals in the Keweenaw Copper district.