ABSTRACTS OF RECENT THESES AND DISSERTATIONS ON GEOLOGY AND RELATED SUBJECTS

By

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Akers, J. P., M.S., The Chinle formation of the Paria Plateau area, Arizona and Utah.

In the Paria Plateau area of northern Arizona and southern Utah the Chinle formation of Upper Triassic age consists of a thick series of lenticular sandstone, siltstone, claystone, and limestone. The series thins northwestward from about 900 feet at Lees Ferry, Ariz., to about 600 feet at Paria, Utah.

Four members of the Chinle formation are recognized—1) the basal Shinarump member composed of conglomeratic sandstone and subordinate shale, 2) a unit, herein named the Lowery Spring member, composed of sandstone and mudstone, 3) the Petrified Forest member composed of bentonitic siltstone and claystone and thin sandstone, and 4) the Owl Rock member composed of cherty limestone and calcareous siltstone.

Only the Petrified Forest member is present at all localities in the Paria Plateau area. The Shinarump member was deposited in topographic low areas on an erosion surface and its distribution is irregular. The Lowery Spring and Owl Rock members grade and pinchout toward the northwest and are not present at Paria, Utah.

The upper contact of the Chinle formation is locally unconformable.

The three lowermost members were deposited on a broad, flat plain between the Cordilleran geosyncline and highlands to the southeast. In Owl Rock time the rising Cordilleran geanticline cut off the northwestward drainage of Chinle streams and a depositional basin trending southwest was formed.

Autrey, William L., M.S., The electrodeposition of zinc from solution obtained by the dissolution of zinc from sphalerite with ammoniacal solutions at elevated temperatures and pressures.

The objective of the research described in this thesis was to determine the conditions required to satisfactorily recover zinc by electrolysis from solution produced by the dissolution of zinc from sphalerite with ammoniacal solvent at elevated temperatures and pressures.

Synthetic solution was used for the first phase of the experimental work in order to determine the general conditions for electrolysis without the interference of impurities. The solution was prepared from chemical grade zinc oxide, ammonium sulfate, and aqua ammonia.

When using steel anodes, the electrolysis gave a deposit which turned black and spongy after a period of time which varied with the current density and glue content.

When electrolyzing with platinum, lead, or fabric encased steel anodes, the deposit was bright and firm.

The treeing which occurred along the edges of the plastic tape placed around the edges of the cathode was eliminated at current densities lower than 30 amperes per square foot by utilizing a high rate of circulation or vigorous agitation.

A stock leach solution was prepared in a two-liter capacity autoclave under a partial pressure of oxygen with a charge of zinc concentrate, water, and ammonia.

The purification of the leach solution consisted of the addition of zinc powder to reduce the concentration of those metals less active than zinc, followed by the addition of ferrous sulfate, its oxidation to the ferric state, and the coprecipitation of iron, silica, arsenic, and selenium.

A current efficiency of 71.9 per cent and a power consumption of 1.51 kilowatt-hours per pound of zinc resulted when electrolyzing at the most satisfactory current density of 25 amperes per square foot for a depletion of 60 per cent. The deposit obtained analyzed 0.07 per cent of lead and less than 0.005 per cent of copper.

Increasing the depletion of zinc increased the power requirement and resulted in a lower current efficiency.

Increasing the cell temperature from 33 to 50 degrees Centigrade had no observable influence on the power consumption or current efficiency.

Recycling of the depleted electrolyte did not affect the leaching recovery. However, the build-up of lead in the electrolyte was excessive.

Barkdoll III, Ivan Harry, M. S., The development of a method for the determination of the optimum replacement time for surface mining equipment.

The object of the research described in this thesis is to develop a method of determining the optimum replacement time for surface mining equipment.

This thesis defines replacement and shows the significance of the factors associated with replacement. Examples show that in many cases there is a decline, with age, in the service produced by equipment. At the same time the cost of maintenance rises as the equipment ages. When aging equipment reaches a certain point, replacement is more economical than continued operation.

Several accepted methods of determining the replacement point for equipment are discussed and examples using these methods are given. There is one main factor in common with all the existing replacement methods. They all depend on an accurate, detailed record-keeping system. These methods all consider slightly different aspects of replacement, but they cannot be used on a unit basis for a large fleet of mining equipment.

The invention of the digital computer and the widespread use of the data processing equipment provides an ideal means of equipment record-keeping. The electronic data processing replacement system developed in this thesis enables a company to maintain an excellent set of equipment ownership and operating cost records. By recording the weekly maintenance data, on IBM punch cards, and using this program, a company can obtain a set of weekly, monthly, and quarterly cost records for each piece of equipment. When these costs and cost ratios are plotted, over a long period, trends are developed that significantly aid in determining the optimum replacement time.

The use of the electronic data processing replacement system is illustrated with the analysis of the complete records for a D-8 Caterpillar tractor over a 150-week period. By slightly changing the forms of the input and output data, the system can be applied to any type of surface mining equipment.

Bennett, Paul J., Ph. D., The economic geology of some Virginia kyanite deposits.

The kyanite quartzite deposits at Leigh, Baker and Willis Mountains located in the south central Virginia Piedmont were investigated to determine their genesis, extent, and geologic and petrographic character. Kyanite quartzite in Virginia typically contains 20-40 per cent kyanite, 0-5 per cent pyrite, 0.5-1.5 per cent rutile, a per cent or so of mica or clay with the balance quartz. They occur as single beds within metamorphic rocks ranging from slates and phyllites of the greenschist facies south of Leigh Mountain, to schists and gneisses of the amphibolite facies at Baker and Willis Mountains. Post- kyanite hydrothermal alteration along fractures has altered large segments of the Baker Mountain deposit to clay and topaz.

The protolith of kyanite quartzite is believed to have been extraordinarily pure mixture of quartz and kaolinite which was produced by either lateritic weathering or by circulating meteoric waters. Isochemical regional metamorphism is believed to have occurred in a high pressure, moderate temperature environment in which water was either deficient or able to escape. Fluorine may have had a catalytic effect in promoting kyanite crystallization. No evidence was found of hydrothermal introduction of alumina, or localization of kyanite as a result of differential stress.

The rocks enclosing kyanite quartzite in the Leigh Mountain area are believed to be basal members of the lower Paleozoic(?) Volcanic-Slate series. The gneisses surrounding Willis and Baker Mountains may be more highly metamorphosed, infolded remnants of the same series.

The kyanite deposits of Virginia are extensive and well situated for mining. Possible reserves of kyanite quartzite containing over 25 per cent kyanite available for open pit mining are measured in tens of millions of tons.

Breed, William, M. S., River terraces and other geomorphic features of Castle Hill Basin, Canterbury, New Zealand.

Extensive systems of terraces in Castle Hill Basin are evidence for widespread cycles of aggradation and degradation of the rivers. The surfaces formed during periods of aggradation have been named as follows: Bridge Hill surface, Long Spur surface, Enys surface, Cheeseman surfaces and Post-Cheeseman surfaces. Evidence from moraines indicates that these aggradational surfaces were created during periods of glaciation when the streams of the valley were overloaded. Degradation and valley deepening ensued during non-glacial conditions, leaving the former river floodplains preserved as glacial terraces. The terraces of Castle Hill Basin have been correlated with similar surfaces in the Waimakariri Valley described by Dr. Maxwell Gage.

Clay, Donald W., M. S., Late Cenozoic stratigraphy in the Dry Mountain area, Graham County, Arizona.

Around the base of Dry Mountain a series of unconsolidated Quaternary sediments of fluvial and lacustrine origin have been deposited. These sediments consist of massive deposits of silt, thin limestone units, and a massive bed of diatomite. The limestone and diatomite contain lenses of chert. The dip of these sediments is approximately 2° to the southeast. Local dip directions vary considerably, and are a result of slumping of the beds and primary dip over irregularities in the basement rocks.

Old stream channels that were penecontemporaneous with the limestone and silt deposits are found throughout the area of study.

Mechanical and statistical analyses of the clastic sediments, and petrographic study of the heavy mineral suite were made. These reveal that the source area for both the channel sand and the silt deposits was the Whitlock Hills.

Thin section study and insoluble residue analyses were performed on the limestone. Both techniques were found to be unsuitable for correlation because of the similarity between the four limestone units in the area.

Dickinson, Robert G., M. S., Correlations of the El Paso formation in western Texas, southwestern New Mexico, and southeastern Arizona based on insoluble residues.

Insoluble residues have been used as a basis for subdividing the El Paso formation into seven zones. Published paleontological data were used, where available, to support the delimitation of the zones. Residues from lower Canadian rocks contain a white to gray smooth chert, whereas overlying Canadian rocks have a chert that is olive brown to black in color.

The sandy dolostone beds at the base of the El Paso formation in the Franklin Mountains, Texas, have tentatively been considered to be of Upper Cambrian age. This is based on the Upper Cambrian age of the basal El Paso formation dolostones in the Dos Cabezas Mountains of Arizona, and the lithologic and residue similarities between the two sections. Lower Canadian sediments thin to the east, north, and west from the area of the Big Hatchet Mountains of New Mexico, suggesting that in the area a basin of deposition existed which had a structurally stable periphery that received little or no sedimentation.

Evensen, James M., M. S., Geology of the Copper Hill area, Winkelman, Arizona.

The Copper Hill area contains the following rock units: (1) older Precambrian granite and leucogranite porphyry, (2) younger Precambrian Apache Group, (3) pre-Middle Cambrian diabase, (4) Cretaceous(?) andesite, and (5) Laramide(?) quartz monzonite-quartz diorite and associated aplite.

There is possible economic mineralization in this area. Primary mineralization of chalcopyrite and some bornite is related to the quartz diorite. Some chalcopyrite occurs in the diabase. Secondary minerals, largely in the fractured granite, consist of cuprite, malachite, and azurite.

The control for the primary mineralization is the favorable host rocks—quartz diorite and diabase. Controls for the secondary mineralization are clay or carbonate coated shears, or joints and rock contacts.

Fractures in the area trend northwest and east. These form favorable zones for later intrusion of diabase, andesite, and quartz diorite. There are distinct joint patterns in each rock unit. Flow structure, present in the granite adjacent to the quartz diorite contacts, was probably produced at the time of the quartz diorite intrusion when enough heat and pressure was present to remobilize the granite.

Frazier, Robert H., M. S., The Ft. Apache limestone of east central Arizona.

The Ft. Apache limestone outcrops from Ft. Apache, Arizona, to Pine, Arizona, along the Mogollon Rim. Generally, its position in the surface exposures is about 400 feet below the top of the Supai formation. Northward, in the subsurface, it is approximately 1,000 feet beneath the top of the Supai formation.

In the area of the Ft. Apache Indian Reservation, the Ft. Apache limestone is a hard, dark gray, finely crystalline, fossiliferous limestone, with a characteristic lower recess of less resistant siltstone. In this area, the limestone is termed a biomicrite. To the west, is a facies change to a light gray, non-fossiliferous, extremely silty limestone, which is termed a calclithite. In the subsurface to the north, the Ft. Apache horizon is primarily a dolomite.

The Ft. Apache limestone attains its maximum thickness of 126 feet in the Ft. Apache area. To the west, near Pine, the limestone thins to only 39 feet, and presumably, pinches out entirely in the area north of Sedona.

The Ft. Apache limestone is of probable Wolfcampian and Leonardian age, and probably correlates with the Colina limestone of the Naco group of southern Arizona.

Fries, Carl, Jr., Ph. D., Geology of the State of Morelos and contiguous areas in south-central Mexico.

The area described lies in south-central Mexico and embraces all but the southeastern corner and easternmost border of the State of Morelos, the second smallest State in the Mexican Republic. It includes small contiguous parts of the State of Mexico, in the northeastern corner, and of the State of Guerrero in the southwestern corner. Limiting geographic coordinates are $98^{\circ}45'$ to $99^{\circ}39'$ west longitude and $18^{\circ}18'$ to $19^{\circ}08'$ north latitude, the northern boundary being only 35 km. south of Mexico City, capital of the Republic. The geologic map does not cover the entire rectangle outlined, but is irregular in form and measures roughly 4150 sq. km., three-quarters of it representing two-thirds of the State of Morelos and the rest lying outside the State.

The region ranges in altitude from 730 m. above sea level at Iguala near the south edge of the map, to a general level of about 3000 m. at the north edge, although individual peaks rise to 3900 m. and Popocatepetl Volcano, a few kilometers east of the northeastern border of the map, rises to 5452 m. above sea level. Annual rainfall ranges from a minimum of about 640 mm. in the low country, to 1200 mm. and more at altitudes above 2000 m. Most of it falls in summer between June and September. Winter frosts are rare below 1800 m. The climate is of savanna to steppe type; soils are thin and may be classified as belonging to the tschernosem group, with strong development of calcareous evaporites (caliche) at altitudes below 1800 m.

The northern border of the area forms the southern half of the late Pliocene to Recent Neo-volcanic Belt of basic volcanism that crosses Mexico in the direction N. 80° W., and thus has constructional topography. The rest of the area belongs to the Balsas Basin physiographic province, which is characterized by maturely dissected terrain tributary to the large Balsas River. All but the southwestern corner of the area drains southward via the Amacuzac River into the Maxcala-Balsas River, and thence westward into the Pacific Ocean. The southwestern corner drains directly into the Balsas River via the Iguala River. Local relief is of the order of 300 to 600 m. The mature topography was partly buried by late Pliocene alluvium in the central part of the area, owing largely to local volcanism. Dissolution of limestone, dolomite, and anhydrite of the Cretaceous formations has produced sinks and poljes, some of which contain small lakes. Other karst features are also common, such as caves, caverns, underground rivers, and surficial lapies or karren. Drainage blocking by lava and polje development in late Pleistocene and Recent time produced new alluvial flats in this otherwise dissected region.

The oldest rock unit in the region is the Taxco schist series of late Paleozoic(?) age. It was folded, metamorphosed, foliated, intruded by dikes, and strongly eroded before the next unit, the Taxco Viejo green volcanic series of Late Triassic(?) age, was deposited. Another period of metamorphism and erosion followed before the calcareous clastic sediments of the Upper Jurassic(?) Acahuizotla formation were laid down. The next unit consists of the partly phyllitic calcareous shale of the Acuitlapan formation, which is of Neocomian(?) age and rests with at least disconformity on the Acahuizotla formation. The overlying Aptian-Barremian Xochicalco formation of thin-bedded limestone appears to grade upward from the Acuitlapan formation, locally, but it seems to be unconformable elsewhere. All these units have small outcrops in the area mapped and were not studied in detail.

Warping and erosion occurred before the overlying Morelos formation began to accumulate in early Albian time. The basal member is anhydrite in the eastern part of the area mapped, but limestone and dolomite were deposited elsewhere. The formation consists largely of shallow-water calcareous bank deposits, with a maximum thickness of about 900 m. Deposition ceased in early Cenomanian time and further warping occurred, possibly accompanied by intrusion of the Coxcatlan, Buenavista, and Colotepec granitic stocks. The next formation consists of the Cuautla limestone of Turonian age, which rests disconformably upon the Morelos formation. It represents a thick calcareous bank (750 m.) in the eastern half of the area mapped, but westward it wedges out and interfingers with the overlying calcareous clastic sediments of the Mexcala formation, which may be of latest Turonian age at the base in some places and of early Coniacian age elsewhere. The Mexcala formation is at least 1200 m. thick and accumulated until Santonian or possibly Campanian time, when the region was uplifted and was not again submerged.

A period of strong folding occurred probably in early and middle Eocene time, concomitant with the Laramide folding farther north. As folding tapered off, intrusion of dikes and stocks, strong faulting, and extrusion of basic lavas began, accompanied by accumulation of thick (more than 2000 m.) clastic deposits of the Balsas group on downfaulted blocks in latest Eocene and early Oligocene time. Rhyolitic volcanism then commenced in the south to form the Tilzapotla rhyolite series, and intermediate volcanism soon began all over the region, forming the Tepoztlan formation, Buenavista volcanic series, Zempoala andesite series, and other Undifferentiated volcanic rocks, all of latest Oligocene to earliest Pliocene age. Local unconformities developed between the units, and dikes and small stocks were emplaced here and there.

Renewed faulting, outbreak of Nevado de Toluca (Xinantecatl) and Popocatepetl Volcanoes, and accumulation of the Cuernavaca formation followed in middle and late Pliocene time. Basaltic volcanism then began in the Neo-volcanic Belt and cut off drainage from what is now the upper Lerma valley and the former Nexico valley, reversing drainage in the former and turning the latter into an endoreic basin. Deposition of the Cuernavaca formation was halted, and the basaltic range along the northern border of the area was built. The Neo-volcanic Belt is thought to be a part of Menard's Clarion fracture zone of the Pacific Basin, as already suggested by him, but its age inland is not believed to be older than middle Pliocene. The belt is thought to represent the surficial expression of incipient left-lateral transcurrent faulting in the subcrust. Activity continues along it to the present day.

Gray, Irving B., Ph. D., Nature and origin of the Moenkopi-Shinarump hiatus in Monument Valley, Arizona and Utah.

The Triassic age Moenkopi Formation, prior to recent erosion, was less than 20 feet to about 450 feet thick in the Monument Valley region of southeastern Utah and northeastern Arizona. The top of this formation is a Triassic age surface of erosion; coarse-grained Shinarump deposits rest upon this surface across the beveled strata of the Moenkopi in much of this region. Each of the four members which constitute the Moenkopi Formation in Monument Valley thins in a southeast direction, indicating that formational thinning in that direction may have been, in part at least, a feature of deposition.

The surface of erosion is believed to have been formed prior to, and during, deposition of the Shinarump and certain other Lower Chinle deposits. The final form of the surface in Monument Valley probably resulted from Shinarump age modification of a pre-Shinarump valley system, and by later Shinarump age pedimentation which produced a broad erosion surface of low relief across the low Moenkopi hills and older Shinarump valley-fill deposits.

It is believed that the streams which deposited the latest Moenkopi were incised into the Moenkopi Formation during a regional uplift which brought Moenkopi deposition to a close. These streams may have continued to erode the pre-Moenkopi outcrops of their headwater areas and to transport this material through their valleys much as they had done during Moenkopi time. After a period of time the downcutting must have ended and the coarsest sediments in transit came to rest in the valley bottoms as earliest Shinarump. Valley widening followed as the streams aggraded their valleys during Shinarump time. The valleys were progressively opened upward during aggradation until the streams and their deposits coalesced across the interfluve areas and formed the Shinarump blanket deposit.

The Shinarump blanket deposit was emplaced upon the older Shinarump valley fills and adjacent beveled Moenkopi strata by streams at grade; i. e., by streams whose gradients were such that they provided just the velocity required to transport all of the supplied load. The surface upon which this blanket rests is a pediment surface. The Shinarump valley fills and pediment mantle were deposited pari passu with the development of the erosion surface in those areas where Shinarump was deposited. Thus, the long lapse of time between the Moenkopi and Shinarump is represented by both the unconformity and the gravel sheet.

Groves, Rees D., M. S., The recovery of copper from solutions obtained by the dissolution of copper sulfide minerals at elevated temperatures and pressures.

The purpose of the experimental work described in this thesis was to investigate the recovery of copper from both acid and ammoniacal leach solutions produced by the dissolution of copper from copper concentrate at elevated temperatures and pressures. Leaching was involved only in the production of solution for the experimental work.

The Recovery of Copper from Acid Sulfate Solutions by Electrolysis

With a current density of 15 amperes per square foot, 86. 7 per cent of the copper was recovered from the electrolyte which contained 56. 16, 20. 53 and 73. 60 grams per liter of copper, iron and free acid respectively. The current efficiency was 67. 1 per cent and the power consumption was 1. 11 kilowatt hours per pound of copper.

A cyclic leaching and electrolysis test of five cycles was conducted in which 90. 1 per cent of the copper was recovered as cathode copper and 6. 7 per cent as sponge copper. The sponge was redissolved in the next leaching cycle. Part of the spent electrolyte was utilized to provide the acid for the leaching of each cycle.

The extraction attained was 96. 2 per cent. The current efficiency and power consumption for the fifth electrolysis was 73. 7 per cent and 1. 00 kilowatt hours per pound of copper respectively.

Analyses of the first and fifth electrolytes for certain impurities did not indicate appreciable build-up.

The Recovery of Copper from Ammoniacal Solutions by Electrolysis

During preliminary work five major problems developed, namely: pitted, whiskered and spongy deposits, redissolution of the deposited copper and variations in current efficiencies.

Electrolysis below the hydrogen discharge potential prevented the spongy deposit and anionic surface active agents eliminated the pitted deposits. A method was not found to suppress the whiskered deposits.

The redissolution of the cathode by the electrolyte was found to be quite appreciable and the redissolution resulted in the formation of cuprous ions.

The current efficiency was found to be 63 plus or minus 3 per cent and the power consumption was 1.06 plus or minus .05 kilowatt hours per pound of copper when circulation was not employed.

Halva, Carroll, M.S., A geochemical investigation of "basalts" in southern Arizona.

Very little work has been done with the post-Cretaceous "basaltic" flows of southern Arizona even though they outcrop over quite an extensive area. In this report a geological and a chemical study have been combined in an attempt to learn more concerning the general nature of these rocks. Samples have been collected and have been subjected to alpha and beta counting, petrographic and handspecimen identification, major chemical analysis, flame photometric analysis, emission spectrographic analysis and neutron activation studies.

Geologically these flows represent the latest igneous activity in this area. They are probably Plio-Pleistocene in age. They usually overlie either andesites or sediments. The basal member is a distinctive, very porphyritic basaltic andesite of uniform chemical and mineralogical composition. Petrographically and handspecimen-wise the upper members would probably be classified as olivine basalts. However, combining both chemical and mineralogic criteria, they are potassic basaltic andesites.

Alpha and beta counting indicate that the potassium content is much too high for a normal basalt. Flame photometric analysis also verified this. Major chemical analyses indicate that these flows have a composition similar to Daly's average diorite. This discrepancy between the petrographic classification and the chemical classification represents incomplete crystallization. Evidence for this exists in the nature of the groundmass which contains the bulk of the potassium probably in the glassy material usually found in each sample. No identifiable primary minerals were present.

Alpha and beta counting, emission spectrographic work and neutron activation studies have been used in the determination of trace constituents. The results of this work indicate that a chemical study coupled with a geological study enables one to more thoroughly understand geologic processes.

Hammer, Donald F., M.S., Geology and ore deposits of the Jackrabbit area, Pinal County, Arizona.

The Jackrabbit area is situated at the north end of Slate Mountains, Pinal County, Arizona. Here, low but rugged hills encompass an apparently conformable sequence of Late Precambrian, Cambrian, Devonian, and Mississippian sedimentary rocks and Late Precambrian(?) diabase sills. Dikes and sills of Tertiary andesite porphyry, and associated pebble dikes, intrude these sedimentary and igneous rocks, and alluvium surrounds their tilted, faulted surface exposures.

Severe structural deformation began with local tilting and intrusion of andesite porphyry. Strike movement along major northwest-trending Boundary faults, and compression resulting from an expanding magma chamber, produced thrust faults, drag folds, tear faults, and pervasive bedding plane rupture. Relaxation of stress allowed downdropping of a structural block along the northwest-trending Boundary faults, and erosion now reveals a graben of Paleozoic sediments between horsts of Precambrian rock.

Thermal solutions rose through the rocks of the Jackrabbit area effecting sericitization of andesite porphyry, silicification of limestone, and the introduction of ore minerals. Outpourings from springs, and the deposition of travertine, marked the termination of hydrothermal activity.

Gold and oxidized lead, zinc, and silver minerals are found with quartz, limonite, and manganese oxide in northeast-striking veins. These ore minerals also replace brecciated, silicified Escabrosa limestone along northeast-striking feeding fractures.

Hedge, Carl E., M. S., Sodium-potassium ratios in muscovites as a geothermometer.

A suite of thirty muscovite samples was collected. The majority of these were from the Santa Catalina Mountains in Pima County, Arizona. The remainder were from a wide variety of geologic settings in which the geologic environment would enable one to make some reasonable estimate as to the temperature of formation of the muscovite.

Analytical techniques for sodium and potassium, capable of yielding a high degree of precision and accuracy, were developed and applied to the suite of samples. The analytical results were then compared to the phase diagram for the muscovite-paragonite join, and the indicated temperatures were considered in relation to the geologic environments. The results were very encouraging. The highest indicated temperatures were at apparently intrusive contacts. Muscovites from gneisses indicated temperatures that were reasonable in light of their mineralogic settings. They ranged from 390°C to 550°C. Samples from pegmatite bodies indicated temperatures between 400°C and 520°C. These results supported the belief that the amount of sodium substituting for potassium in the muscovite structure would be a fairly valid geothermometer.

This technique was also used as a tool in studying the metamorphic complex in the Santa Catalina Mountains.

Hewlett, Richard F., M. S., A comparison of various methods of calculating ore reserves using a digital computer.

The applicability of the digital computer to the calculation of ore reserves is demonstrated by description of developed programs and by indication of operation times and costs. Comparisons of the triangular and polygonal methods of calculating ore reserves are made. Specific uses of IBM data processing equipment applied to some mining problems are discussed.

The use of high-speed data processing methods and a few statistical techniques for a mineral deposit analysis are proposed and illustrated. Other additional areas in the Mineral Industry for further research in the application of digital computers and statistical methods are suggested.

Howell, Paul W., Ph. D., The Cenozoic geology of the Chetoh country, Arizona and New Mexico.

Kothavala, Rustum, M. S., A study of the remnant magnetism of Granite Mountain, Iron Springs District, Utah.

Granite Mountain is a laccolithic intrusion of quartz monzonite in the Iron Springs district of southwestern Utah. The intrusion is associated with peripheral replacement deposits of iron ore.

The orientation of the remnant magnetism of 50 samples from Granite Mountain was determined using a specially constructed astatic magnetometer. The magnetometer is capable of detecting fields of the order of 10^{-7} oersteds.

The orientation of the remnant magnetism vectors show two important features. First, vectors with similar orientations exist in geographic domains and secondly, a majority of the vectors are close to the modal azimuth of N 6^{o} W. The present azimuth of the earth's magnetic field at Granite Mountain is N 16^{o} E.

The author believes that the magnetic domains were caused by strong, local magnetic fields. These fields were due to ore bodies that exist or that may have existed in the vicinity of each domain.

The modal azimuth of the remnant magnetic vectors is interpreted as being due to the earth's magnetic field at the time the remnant magnetism was acquired. Some workers have plotted the path of migration of the earth's magnetic pole throughout geologic history. The intersection of this path and the modal azimuth presumably represents the point in time at which the Granite Mountain intrusion was formed. The age of the intrusion, determined by this method, is early Tertiary and this agrees closely with the age determined by geological methods.

Laughlin, A. William, M. S., Petrology of the Molino Basin area, Santa Catalina Mountains, Arizona.

Banded augen-gneisses are closely associated with bands of quartz-dioritic gneiss in the Molino Basin area of the Santa Catalina Mountains. Field evidence suggests that these rocks are gradational in texture and mineralogical composition. Optical and chemical evidence strengthens this theory and indicates that the gneisses had a common sedimentary origin and underwent equal degrees of metamorphism.

The writer believes that the different gneisses resulted from the segregation of minerals from a single source material with the end products being almost pure biotite bands and granitic gneiss.

Maddox, George, M. S., Subsurface geology along northwest Rillito Creek.

Drillers' logs of water wells may provide valuable information of the lithologic composition, structure, and permeability of sediments in the subsurface. The most critical factor in using water well drillers' data is proper translation of drillers' terminology into a vocabulary familiar to the geologist. In order to accomplish such translation, many drillers' logs have been studied, and a method of digital expression for the drillers' lithologic terms has been developed in this report. The digital expression is based on grain size and it has been used to differentiate distinct lithologic units in the subsurface and outline the framework of the general geology. A knowledge of the subsurface geology provides an understanding of the occurrence, movement, and recharge of ground water.

Marlowe, James I., Ph. D., Late Cenozoic geology of the lower Safford Basin on the San Carlos Indian Reservation, Arizona.

Terrestrial sediments of late Cenozoic age occur in the bedrock trough of the lower Safford Valley to an unknown depth. These sediments are largely fluvio-lacustrine in origin and have been deposited by the ancestral Gila River, its tributaries, and bodies of water isolated from the main drainage. They are composed of silt, sand, and clay for the most part, but locally limestone comprises the predominant nonvolcanic lithology. A thick series of limestones and pyroclastic sediments is preserved beneath lava flows at the northwest end of the valley. Elsewhere, erosion has removed beds equivalent to these limestones and tuffs and only a lower part of the sedimentary section is preserved. Volcanic vents and breccias are closely associated with the thick limestone accumulation.

The age of the basin fill is considered to be Upper Pliocene to late Kansan. Lower beds are equivalent to those near Safford, Arizona, which have been dated on fossil evidence as Kansan. The upper part of the section is probably considerably younger than the Safford beds.

Deposition of the basin fill took place on a wide fluvial plain of low gradient, in an environment somewhat more moist than prevails today. Sluggish drainage allowed the formation of ponds and lakes of varying duration. Streamflow from the adjacent mountains locally deposited gravel in alluvial fans which interfinger with the fine-grained basin fill. Volcanic activity at the west end of the valley caused disruption of drainage by ash falls and lava flows, allowing the accumulation of chemical limestone in isolated basins. Due to aggradation and damming by lava flows, the Gila River reoccupied its ancient channel through the Mescal Mountains and proceeded to cut its present gorge, ending deposition in the basin and initiating erosion. Subsequent climatic change caused bevelling of the basin-fill beds by erosion surfaces, an older one of which is now preserved beneath lava flows.

Mathias, William F., Jr., M. S., Detrital mineral studies of some Cenozoic sediments, Safford Valley, Arizona.

More than 27 mineral species have been identified in Cenozoic sediments of varying lithology within the Safford Valley of Arizona. The mineral assemblages suggest the following possible sources for the basin-filling detritus: (1) acid igneous rocks, (2) basic igneous rocks, (3) high-rank metamorphic rocks, (4) reworked sediments, and (5) explosive volcanic activity.

The high angularity and low stability of most of the heavy minerals suggests that the crystalline rocks of the mountains that flank the valley were the source of most of the detritus. The presence of glass and fresh euhedral volcanic minerals suggests that explosive volcanic activity has also contributed greatly to the detritus that fills the valley.

The use of heavy minerals as a means of differentiation and correlation of strata must be based upon frequency of occurrence of mineral species, rather than on any major mineralogical changes.

The uniformity of the general heavy mineral suite over a considerable vertical and lateral range, and the characteristic lenticular and discontinuous nature of the Cenozoic sediments, may make the determination of mineral zones difficult.

McColly, Robert A., M.S., Geology of the Saguaro National Monument area, Pima County, Arizona.

In the west end of the Saguaro National Monument the Catalina gneiss which forms Tanque Verde Ridge is separated from a pediment cut in granite and schist by a major northeast-trending fault. The latter rocks were believed by B. N. Moore, et al. (1941), to be the Oracle granite and the Pinal schist, both Precambrian in age. Evidence collected in preparation of this thesis indicates that neither unit is older than Cretaceous. The schist is bounded on the north and south by steep normal faults along which vertical movements have occurred. The relative amount of movement served to control the later erosion of the blanket of Miocene(?) Pantano sediments which overlie the schist and granite. These faults also formed zones of weakness along which intrusive bodies of andesite were emplaced. The andesite and the Pantano sediments were both capped by later flows of rhyolite. Blocks of unmetamorphosed sediments occur lying across the gneiss/granite-schist contact. Moore, et al., considered these rocks to represent a thrust slice of Cretaceous sediments, moved in from the west. Paleozoic fossils reported by J. H. Feth (personal communication), and fieldwork by the author show that the sediments are Permian(?) in age, and that they were probably emplaced from the east by gravitational gliding.

Michel, Fred A., Jr., M.S., Geology of the King Mine, Helvetia, Arizona.

Sulfide minerals occur in silicated limestone at a contact of a quartz monzonite porphyry stock.

Some zoning of the primary silicates was observed. Many features of the zoning are difficult to explain on the basis of thermal gradients. Some chemical difference in the environments of deposition is suggested as an alternative explanation.

The silicate mineral assemblage which replaced the original limestone was subsequently altered and sulfide ore minerals were deposited mainly in the transition zone between completely silicated rock and unaltered limestone. The major ore zones were controlled by rolls in the porphyry contact and associated fracturing.

Host rock favorability appears to have been the major control of individual ore bodies. It is suggested that an ideal composition of the host rock brought about by silicate alteration was the cause of the apparent favorability.

Miller, James B., M.S., Sedimentation studies in the Sabino Canyon area near Tucson, Arizona.

The sediments of the Lower Sabino Canyon area near Tucson, Arizona have been transported and deposited in an arid environment, and as a result represent a departure from the typical fluvial deposit. The lack of precipitation in the region has two effects upon the sediments. Chemical weathering of the canyon slope and stream materials is almost completely lacking. As the second consequence, sediments are not transported for long distances or over long periods of time, and as a result the physical changes of the stream materials are very slight.

The slope and stream deposits are primarily sandy gravels and gravelly sands, poorly to moderately sorted, and angular to subangular. Values of the mean size, inclusive graphic standard deviation, inclusive graphic skewness, and graphic kurtosis help to illustrate the apparent coarseness and general lack of sorting of the sediments.

Mineralogically, the sediments reflect the composition of the source rock, the Catalina gneiss. Feldspar dominates quartz while garnet is the dominant mineral of the two heavy mineral groups—garnet-magnetite and epidote-hornblende-apatite.

Moore, Robert A., M.S., Cretaceous(?) stratigraphy of the southeast flank of the Empire Mountains, Pima County, Arizona.

A probable minimum of 8,100 feet of Cretaceous(?) sandstones, siltstones, shales, conglomerates, and limestones lie disconformably on Upper Permian limestone on the southeast flank of the Empire Mountains. Two major units, the lower consisting of predominantly coarse clastics, and the upper consisting of finer grained clastics, may be separated. The section, while cut by numerous faults and fractures, is nearly complete except that some of the top beds are not exposed. Two main structural trends, north-west and north-south, are shown by the fracture pattern.

Vertebrate and invertebrate fossils of probable Upper Cretaceous age found to the south of the area, the nearness of Upper Cretaceous rocks in the Santa Rita Mountains, and the relative distance of Lower Cretaceous Bisbee group from this area show that the probable age of these rocks is Upper Cretaceous.

Nations, Jack Dale, M.S., The Black Prince Limestone of southeastern Arizona.

The Black Prince Limestone in southeastern Arizona has previously been assigned a Mississippian age. Paleontological evidence for this age has been scanty with emphasis being placed on the occurrence of *Lithostrotionella shimeri* (Crickmay) in the basal two feet of the formation. Results of the recently completed field and laboratory investigation show that *Lithostrotionella shimeri* in the Black Prince Limestone occurs in a residual accumulation from erosion of the underlying Escabrosa Limestone (Mississippian). An assemblage of five coral genera found in the Black Prince Limestone correlates with Lower Pennsylvanian (Morrowan) fauna in the Marble Falls Limestone of central Texas. The occurrence of *Millerella* throughout the formation, as well as Atokan Fusulinids at the base of the overlying Horquilla Limestone (Pennsylvanian), indicates a Morrowan age for the Black Prince Limestone.

Olson, Harry J., M.S., The geology of the Glove Mine, Santa Cruz County, Arizona.

The Glove Mine is located on the southern extremity of an isolated synclinal sedimentary block of Paleozoic and Cretaceous sediments on the southwest flank of the Santa Rita Mountains.

Solutions probably associated with a quartz monzonite intrusive, emplaced to the south of the Glove fault, have deposited argentiferous galena, sphalerite, and lesser amounts of quartz, pyrite, and chalcopyrite along permeable zones caused by bedding-plane fault intersections within a favorable limestone horizon of the Naco group. A pre-ore latite porphyry sill has prevented the spread of the mineralizing fluids into the limestones and siltstones to the north on the upper levels of the mine by acting as a deflecting barrier which has channeled the ascending mineral solutions along its footwall side.

As the result of extensive oxidation, only relics of the primary sulfides exist in the mined portion of the deposit. Cerussite, lesser amounts of anglesite, wulfenite, smithsonite, and other products of the oxidation of the primary sulfides, have been concentrated in caverns leached along the mineralized zone by acids formed by atmospheric CO_2 and the oxidation of pyrite.

A zone of increased silver values occurs at the interface between the oxide and sulfide zones.

Mining at the Glove terminated at the top of the sulfide zone after producing over 21,000 tons of ore worth slightly over one million dollars.

Padan, John W., M. S., Optimum combination of truck and shovel size for open pit mining.

Contemporary techniques of estimating costs per hour of owning and operating open pit mining equipment are discussed, and a recommended procedure is illustrated through the use of sample problems.

The application of a digital computer is demonstrated by calculating the total ownership and operating costs per hour of all equipment concerned for each of 28,350 combinations of truck size, shovel size, and haul distance. From these data a chart has been developed which indicates the most economical truck size to use for a particular shovel size and haul distance.

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

The Coto Francisco and La Minera Occidental Bosch, S. A., are located in the Pinar del Rio province in western Cuba. The oldest rocks on the island, Mesozoic sediments, are found in this portion of Cuba, and strike northeastwardly, parallel to the trend of the island axis. Various mineralized districts are situated within the Pinar del Rio province. These constitute a copper belt which lies on the northwest flank of the ridged province between the centrally located Organ Mountains and the Gulf of Mexico.

Rocks present in the Coto Francisco include the Upper Jurassic San Cayetano formation, the Vinales formation of Lower Cretaceous age, and various igneous rocks.

The San Cayetano formation consists of a thick series of alternating phyllites, slates, sandstones, and quartzites which have locally been intensely folded. Disharmonic folding is common with the phyllite and slate layers being more strongly contorted between more competent sandstone or quartzite layers. The formation strikes northeasterly, and faulting within the formation generally parallels the strike. There is also a cross-cutting tensional fault set which trends northwestwardly and two sets of shear fractures, one striking north-northeast and the other striking west-northwest. The intersection of the two major fault sets plus the fault wedges created by the intersection of the shear faults furnished loci for the development of ore bodies like that present at the Bosch mine.

The mildly metamorphosed Vinales formation is composed of a relatively pure limestone which forms the steep-sided Organ Mountains that extend in a northeastward direction through the province, parallel to the strike of the San Cayetano beds. The Organ Mountains lie southeast of the gently rounded hills which are characteristic of the weathered San Cayetano formation. Between the limestone mountains and the shale hills lies the Valle Francisco, or Francisco valley. It is in this valley that igneous rocks crop out.

Igneous intrusions occur where persistent northwest-trending tensional breaks intersect the dominant northeast-trending fractures. Igneous or meta-igneous rock types represented include serpentinites, amphibolites, and a brecciated intrusive hyalocrystalline andesite. A kinship between these rocks and the ore bodies present in the area may be inferred; though mineralization is nowhere observed intimately related to the igneous rocks, the intrusions are always found in the general vicinity of the ore deposits.

The Bosch ore body, as well as similar deposits contained within the Pinar del Rio copper zone, is localized by structural features. The intersection of northeast-trending faults with northwest-trending tension fractures forms a plunging linear shattered zone which provided the loci for ore deposition. The ore body is correspondingly pipe-like in habit. The ore solutions were locally influenced (within the ore body) by the wedges formed by the intersection of the shear fractures. These fault wedges may be seen on a variety of scales, from a hundred feet or more to a few inches. All of the copper deposits in the area were emplaced in the San Cayetano formation, and the deposition was probably pre-Vinales (post-Upper Jurassic, pre-Lower Cretaceous).

The shattered fault wedges were favored for ore deposition in the upper portions of the ore body, but the limbs of the wedges fan outward with depth to thin, widely-spaced fissures. The mineralization is restricted to these fractures and the ore grade is correspondingly lower.

Sulphide minerals at the Bosch mine include pyrite, chalcopyrite, sphalerite, and galena, introduced in that order. Widespread silicification and less extensive sericitization and chloritization of the wallrock accompanied the introduction of the sulphide material. A poorly developed and discontinuous halo of drusy pyrite locally envelopes the ore body. The mineralization at the Bosch mine is generally similar to that of other copper ore bodies in the province.

Present at the Bosch mine, Matahambre mine, and less noticeably at smaller mines in the area, are outcrops of massive hematite which do not coincide spatially with the ore bodies, but are exposed to the southwest of the ore bodies at the Bosch and Matahambre mines. This material might represent oxidation products from original sulphides, however, no sulphides have been found beneath them. The iron oxide outcrops are aligned with the ore bodies along the northwest tensional direction. Outcrops of igneous material are also commonly found along this alignment.

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

The Bullock Canyon-Buehman Canyon area lies approximately 30 miles northeast of Tucson, Arizona at the southern end of the Santa Catalina Mountains.

The principal rocks in the area are metamorphosed late Precambrian Apache group(?) sediments and Paleozoic(?) meta-carbonates that strike northwest and dip northeast. These rocks contain mineral suites characteristic of a low-medium grade of metamorphism.

Gneissic granite intrudes the Precambrian(?) and Paleozoic(?) rocks and may be Laramide(?) or Nevadian(?) in age.

It is suggested that emplacement of the gneissic granite and metamorphism were contemporaneous.

Unmetamorphosed basic dikes and a monzonite stock comprise less than 1 percent of the area and are late Mesozoic-Tertiary(?) in age.

A fanglomerate overlies the metamorphosed rocks and may be as recent as Cenozoic.

Samii, Cyrus, M.S., The geology of the Flat Rock Oil Field, Upton County, Texas.

The Flat Rock Oil Field is located in the southern part of the Midland Basin, about eight miles east of the town of Rankin, southeast Upton County, Texas.

The discovery well, Cities Service Oil Company No. 1 University "AH", was drilled in 1951 and was completed in a dolomitic zone in the Ellenburger group of Upper Cambrian and Lower Ordovician age. Later in the same year, sandstone horizons of the Spraberry formation of Lower Permian age were discovered to contain commercial oil.

Oil is trapped in the Ellenburger group by a combination of folded and faulted structures. In the Spraberry formation, a simple convex fold, with an east-west trend, is responsible for oil accumulation. The Spraberry trap is bounded also to the east by a decrease in permeability.

Presently, 11 wells produce in the field which to date have yielded a cumulative production of approximately one million barrels of oil. Of this amount of production, approximately 53 percent has come from the Ellenburger dolomite and 47 percent from the Spraberry sandstone. The Ellenburger pay horizon contains about 320 proved acres and the Spraberry pay horizon about 560 acres.

Ultimate primary recovery from the Ellenburger pay is estimated as 580,000 barrels; from the Spraberry, as 1,070,000 barrels. The Ellenburger producing zone does not appear to be amenable to secondary recovery, but secondary recovery from the Spraberry pay may be possible.

Sell, James D., M.S., Bedding replacement deposit of the Magma Mine, Superior, Arizona.

The bedding replacement deposit of the Magma mine is presently the largest contributor of copper ore to the operations of Magma Copper Company, Superior, Arizona.

The ore body is both stratigraphically and structurally controlled. Iron-copper mineralization has extensively replaced favorable units in the lower part of the Martin limestone of Devonian age. Four systems of faults, trending east, northwest, north, and northeast, are found throughout the ore body. Mineralization was introduced in two stages. The iron-rich copper-poor mineralization phase was primarily guided by the east- and northwest-trending faults during the complete and selective replacement of the favorable limestone units. Major movement of the north- and northeast-trending faults offset the pyrite-hematite replaced beds. The late copper-bearing mineralization phase followed the late rotational northeast-trending faults and produced the economic ore body in the iron-replaced limestone beds.

Shride, Andrew F., Ph. D., Some aspects of younger Precambrian geology in southern Arizona.

Feldspathic and quartzose sedimentary formations and cherty dolomites—the latter now largely metamorphosed to silicate-bearing limestones—form a sequence about 1,500 feet thick that comprises most of the Apache group. Individual formations, which represent shallow marine deposits accumulated through a long period of geologic time, are remarkably uniform in stratigraphic details throughout an area of 15,000 square miles in southern Arizona. Tuffaceous sediments in the lowest formation and basalt flows at the top of the group indicate volcanic activity.

The Apache group was mildly folded and eroded before deposition of the Troy quartzite, which accumulated in thicknesses of at least 1,200 feet. After lithification of the Troy these younger Precambrian formations were folded and faulted along widely spaced northerly trending belts, then intruded by minor dikes and extensive sills of diabase, which locally equal the sedimentary rocks in volume. The Troy and older formations were much faulted and displaced as a consequence of diabase inflation. Thereafter the formations were deeply eroded. In the southern part of the region Middle and Late Cambrian sandstones and quartzites, here referred to the Bolsa and Abrigo formations, overlie them. In the northern part of the region the Cambrian formations were eroded away before the Martin limestone of Devonian age was deposited on the Precambrian formations. These relations indicate that the Troy quartzite should be redefined and designated Precambrian in age, and that the major diabase intrusions, heretofore generally considered Laramide, should be assigned to the Precambrian. Wider appreciation that deformation preceded and accompanied diabase intrusion during later Precambrian time will aid in deciphering the structural settings of the mining districts of southern Arizona.

Stiles, Ronald E., M.S., The effects of annealing cold-worked tough pitch copper in reducing atmospheres.

The effects of annealing cold-worked tough pitch copper were investigated. Temperatures in the range of 700°F to 1300°F were applied for selected times while specimens which had been cold reduced 25%, 50% and 75%, were annealed in atmospheres containing from 1% to 15% hydrogen. Correlations between these stated variables were sought. The manner in which the degree of embrittlement was promoted by increases in temperature, time at temperature, hydrogen concentration and prior cold-work was determined. Structural aspects of embrittlement were studied by micro-examination and the effect on mechanical properties was investigated.

Taylor, Omer J., M. S., Correlation of volcanic rocks in Santa Cruz County, Arizona.

New field work and studies made by previous workers show remarkable similarities in the sequences of volcanic rocks in Santa Cruz County and the Tucson Mountains, Arizona. These sequences consist of Cretaceous(?) andesite and rhyolite; Tertiary andesite, rhyolite, tuff, rhyolite-latite, and andesite; and Quaternary(?) basalt. These sequences also have structural similarities since the Cretaceous(?) rocks are usually badly deformed, the Tertiary rocks are often gently tilted, and the Quaternary(?) rocks are flat-lying. The Tertiary sequence, except for the upper andesites, is dated as ranging from the close of the Cretaceous to early Miocene time by comparing it with the Lower Miocene Mineta beds, the Pantano formation, and the volcanic rocks associated with these sedimentary rocks.

Microscopic studies of the units thought to be correlative show both similarities and dissimilarities in mineralogy. Chemical studies of each volcanic unit consisted of alpha and beta counting to determine the alpha activity and potassium content of each unit as well as emission spectrograph analysis for chromium, copper, magnesium, and calcium. These chemical studies indicate that although the rocks thought to be correlative have chemical differences, each suite also has chemical similarities. Possible extensions of this volcanic correlation throughout southern Arizona, southwestern New Mexico, and northern Sonora, Mexico are suggested but were not studied.

It is concluded that the chemical studies undertaken in this work are of great value in volcanic petrography. The origin of the volcanic sequence is referred to the relation of structural deformation and fusion of rock at different levels in the crust and mantle.

Thackpaw, Saw Clarence, M. S., Geology of the Ruby Star Ranch area, Twin Buttes Mining District, Pima County, Arizona.

The rocks of the Ruby Star Ranch area range from Precambrian to Recent in age. Granite forms the basement rock with quartzite, limestone, and conglomerate lying on top of it. The limestone and quartzite were involved in the Serasio thrust, resulting in brecciation and recrystallization of the rocks. The Helmet fanglomerate, which is believed to have formed from mudflows, covers over half of the area and was intruded by andesite-porphyry dikes in the east. The mudflows were initiated by the Ruby Star fault which trends approximately north-south and cuts the thesis area in the west.

A dearth of outcrops hinders structural study of the area. Thrust faulting, the main structural feature, with normal and wrench faulting, igneous intrusion, and folding make up the tectonic elements of the area studied.

Only a small portion of the area shows mineralization which is associated with common contact metamorphic minerals adjacent to granite intrusions. The structural movements in the area were mostly post mineralization. Any areas of extensive mineralization that might exist are covered by the extensive Helmet fanglomerate.

Towle, Stewart W., M.S., A study of the rate of reaction between PbO and PbS in the solid state.

A study was made of the reaction rate of the reaction, $2PbO + PbS = 3Pb + SO_2$, in the temperature range 1008 to 1073°K, in which range the reactants are solid.

Experimental procedure consisted of reacting stoichiometric mixtures of PbO and PbS at specific temperatures in a tube furnace through which nitrogen was passed. Nitrogen from the furnace was passed through iodine solutions to remove the SO_2. The amount of SO_2 given off in a timed period was determined by titrating the spent iodine solutions. From data obtained the order of reaction was found and specific reaction rate constants determined. The effects of compression of reactants, addition of MgO and addition of SiO_2 were studied.

The data showed that:

a. The reaction is essentially first order.

b. The heat of activation is 60,290 cal.

c. Specific reaction rate constants can be calculated using the Arrhenius equation: $k = 2.18 \times 10^9 e^{-60290/RT}$.

d. Compression of the reactants decreased the reaction rate.

e. Addition of MgO increased the reaction rate.

f. Addition of two per cent or more SiO_2 decreased the extent of reaction and minimized the temperature dependence of the specific reaction rate constant.

Waller, Harold E., Jr., M.S., The geology of the Paymaster and Olivette mining areas, Pima County, Arizona.

The Paymaster and Olivette mining areas are located approximately 25 miles southwest of Tucson, Arizona in the Pima mining district.

Elevations range from 3,950 feet on the west, to 3,500 feet on the east, and drainage is generally to the east.

Paleozoic and Cretaceous sediments and Tertiary intrusives have been thrust over the Precambrian Sierrita granite. Pegmatite dike swarms are found in the granite but apparently carry no minerals of present economic importance.

High-angle reverse and normal faults are found in the San Xavier thrust sheet paralleling its margins. Left lateral tear faults which cut and offset the thrust sheet acted as couples which opened the high-angle faults. These were then mineralized with sulfides of copper, lead, and zinc.

Later intrusive rocks and an intrusive breccia pipe are present in the area. Limonite staining and mineralization and alteration associated with vein deposits in the thrust sheet appear to form a halo around the breccia pipe.

The presence of the widespread halo affects, the complexly fractured rock adjacent to the thrust, the breccia pipe, and the type of mineralization indicate the possible presence of a disseminated type deposit at depth within the area.

Watson, Barry N., M.S., Effects of the August 17, 1959 earthquake and subsequent quaking upon the thermal features of Yellowstone National Park.

The August 17, 1959 earthquake whose epicenter was placed in the Hebgen Lake region of southwestern Montana caused extensive changes within the hydrothermal network of geysers and hot springs in nearby Yellowstone National Park. Although major feature changes due to tectonic and volcanic activities have been noted elsewhere in the world, i.e. Iceland and New Zealand, they had never been recorded in Yellowstone previous to 1959.

The Firehole River geyser basins in Yellowstone National Park lie within an extensive rhyolitic plateau developed in late Tertiary and Quaternary times. Quaternary faulting on this plateau generally trends northwest to north. A similarly northwest-trending fault system was exposed by the 1959 earthquake in pre-Laramide sediments of the Hebgen Lake region 30 miles northwest of Old Faithful village and just off the Rhyolite Plateau. The results of the quake in the Old Faithful area likewise suggest the distinct possibility of a northwest-trending fault control of the thermal features. Although fault control is undisputed in most other thermal regions of the world it has been previously discredited in Yellowstone by such eminent scientists as E. T. Allen and A. L. Day.

The 1959 quaking caused an increase in thermal activity in the Firehole River basins. The average temperature of 167 sample springs increased 6°F, discharge of thermal waters became apparently heavier, and increased eruptive activity was noted. Some springs experienced decreased or cessated activity. The major groups of thermal features in the Firehole River basins are reviewed on a before-and-after basis to show earthquake change.

Thermal feature alignments, interchange of function between various hot springs, new post-quake thermal activity, and structural evidence from enlarged aerial photographs have convinced the author of fault control within the geyser basins. Several faults are mapped showing a general northwest to north trend; however, evidence of such faulting is admitted to be subtle and of extraordinary nature. An extension of this northwest-trending fault system in the Firehole River geyser basins would project into the Hebgen Lake region.

Wilson, Clyde A., M.S., Ore controls of the San Xavier Mine, Pima County, Arizona.

The San Xavier Mine is characteristic of most pyrometasomatic ore deposits although it can not be directly related to any known igneous rock contact. The main ore minerals sought were galena and sphalerite; subordinate values of copper were present. Main alteration silicates present are garnetite and hedenbergite.

The majority of the 7 miles of underground workings are located within the upper Permian Concha limestone formation. Most of the ore bodies were located between the 420 foot level and the 740 foot level; the mine extends to a depth of 900 feet where it appears the ore bottomed. The ore bodies were usually chimney-shaped, and inclined downward at an angle of 55 to 80 degrees to the south.

The major ore control appears to have been the formation of brecciated centers at the intersection of east-west trending normal faults with north-south offsets and south dipping low-angle thrusts. The presence of the dense overlying Cretaceous arkose was important in reflecting the hydrothermal fluids into the limestone. Altered limestone areas rich in garnet and hedenbergite were favored for ore localization.

Favorable areas for future exploration lie at fault intersections to the east and west of the mine site along the limestone-arkose contact.

Yildiz, Mehmet, M. S., Structure and petrography of Black Rock, Apache County, Arizona.

Black Rock, located 1.5 miles south of Fort Defiance, Arizona, is a composite lamprophyric dike 20 to 60 feet wide and approximately 2,500 feet long. In plan it has a crescentic outline and stands 250 to 300 feet above the surrounding valley floor. It is intrusive into the Chinle formation of Upper Triassic age, and is probably of Pliocene age. The plug is composed of at least three different rock types:

1. Green to gray-colored, medium-grained vogesite

2. Dark green to black, fine-grained vogesite

3. Volcanic breccia

The vogesitic rocks represent separate intrusions and the breccia probably formed during the earlier period of intrusive activity.

Microscopically, the mineral composition of the vogesitic rocks is similar. They contain sanidine, diopside, biotite, glassy material, hematite, limonite, magnetite, calcite, apatite, and some chlorite.

There is little evidence of contact metamorphism of the adjacent shale and sandstone, and the intrusive must have been relatively cool and viscous when it was forcibly emplaced.