Some geological features of the Santa Rita quadrangle, New Mexico

Robert M. Hernon, W. R. Jones, and S. L. Moore

1953, pp. 117-130. https://doi.org/10.56577/FFC-4.117

in:

Southwestern New Mexico, Kottlowski, F. E.; [ed.], New Mexico Geological Society 4 th Annual Fall Field Conference Guidebook, 153 p. https://doi.org/10.56577/FFC-4

This page is intentionally left blank to maintain order of facing pages.

but containing a wide variety of types. Domes of rhyolite were in part intrusive and in part extrusive. Doubtless some deformation accompanied this igneous activity. Some water-laid sediments were deposited in basins in the volcanic area. As volcanic activity waned, erosion and deposition of debris became the dominant characteristic of the region. Probably Basin and Range faulting became active as volcanism subsided. Certainly the great volcanic cover was warped, folded gently, and broken by the pattern of Basin and Range faults so that today many of the ranges show volcanic rocks in the positive as well as in the negative areas. The negative areas and positive areas that now are deeply eroded are largely covered with debris so that the structural pattern is largely obscured. The incision of the Rio Grande drainage pattern with consequent removal of debris cover has exposed some negative blocks as well as positive areas so that structure as well as other bedrock features are revealed. In some places, particularly in the Tularosa basin, recent fault scarps show that Basin and Range structural dislocation is still in progress.

SOME GEOLOGICAL FEATURES OF THE SANTA RITA QUADRANGLE, NEW MEXICO

by
R. M. Hemon, W. R. Jones, and S. L. Moore*

Introduction

The basic geology of the Santa Rita quadrangle is well known from the published reports by Paige (1916), Spencer and Paige (1935), Lasky (1936), Schmitt (1939), and Lasky and Hoagland (1948). Since 1948 the U. S. Geological Survey has remapped the quadrangle and a preliminary report is in preparation. Some of the conclusions of the report as well as observations of previous workers in the area are incorporated in this resume of the geology.

Regional Setting

The Santa Rita quadrangle lies on the north rim of the Sonoran geosyncline near the southeastern margin of the Colorado Plateau (See Index map of Sonoran geosyncline). The geologic map of New Mexico shows that it also lies within a prominent belt of east-northeast trend characterized by abrupt changes in the regional strike of the rocks, structural disturbances, and prominent igneous intrusions. A prominent set of northwest-striking faults crosses the northeast belt of adjustment within the limits of the Silver City 30-minute quadrangle. Being on the rim of the Sonoran geosyncline, the region is underlain by a relatively thin blanket of sediments of Paleozoic and Mesozoic age. The comparative lightness of this load had a profound effect on the mode of intrusion of the rocks of Late Cretaceous and early Tertiary age, which is described later in this report.

*Publication authorized by the Director, U. S. Geological Survey.

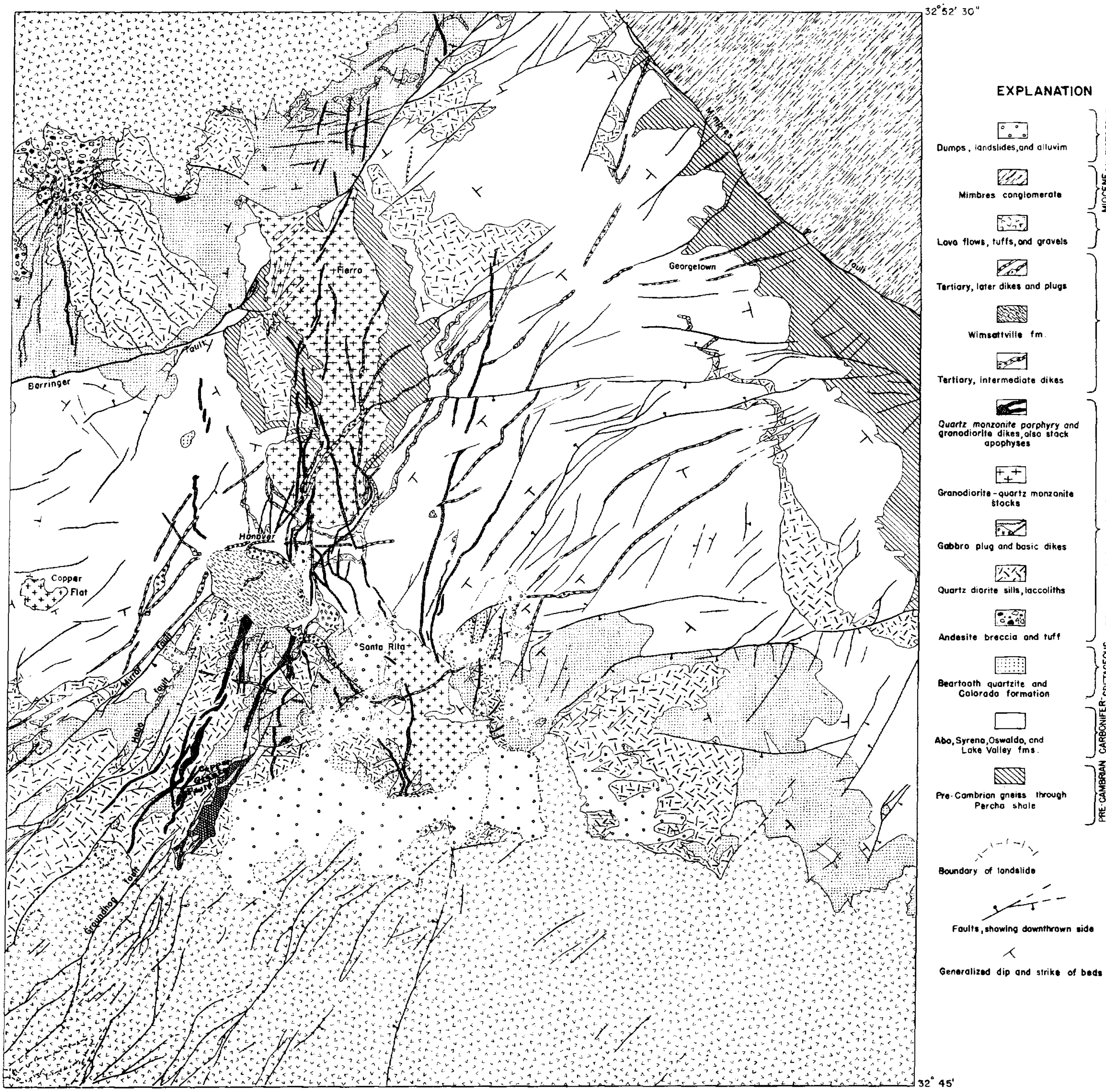
Rocks

General statement – The rocks of the Santa Rita quadrangle consist of sedimentary rocks, intrusive igneous rocks, metamorphic rocks, volcanic debris, lava flows, and gravel deposits. These rocks, which range in age from Precambrian to Recent, include Precambrian spotted hornfels and mica schist; limestone, shale, and sandstone of Paleozoic age; shale, sandstone, and quartzite of Mesozoic age; diorite sills of Late Cretaceous or early Tertiary age, andesitic volcanic breccia and associated intrusives of Late Cretaceous or early Tertiary age, intrusives of intermediate composition of early Tertiary or Late Cretaceous age, latitic intrusives of Tertiary age, rhyolitic pyroclastic rocks and basaltic flows of Miocene (?), valley fill deposits of Miocene (?), Pliocene, and Pleistocene (?) age, and Quaternary alluvium. The areal distribution of the rocks, grouped and generalized for simplicity, can be seen on the accompaning Generalized Geologic Map of the Santa Rita quadrangle.

Sedimentary and volcanic rocks – The general character of the sedimentary and volcanic formations within the quadrangle is given in the table on pages 120 and 121.

The rocks of Paleozoic age are predominantly limestone with some shale and a little sandstone. Dolomite and dolimitic limestones are restricted to the lower beds of Paleozoic age. The aggregate thickness of the Paleozoic rocks is only about 2800 feet. No rocks of Triassic, Jurassic, or Early Cretaceous age were deposited -- at least, no evidence of them remains. The Upper Cretaceous sedimentary rocks aggregate about 1100 feet, which, added to the Paleozoic section, gives a total thickness of only 3900 feet.

Intrusive igneous rocks – The major types of igneous

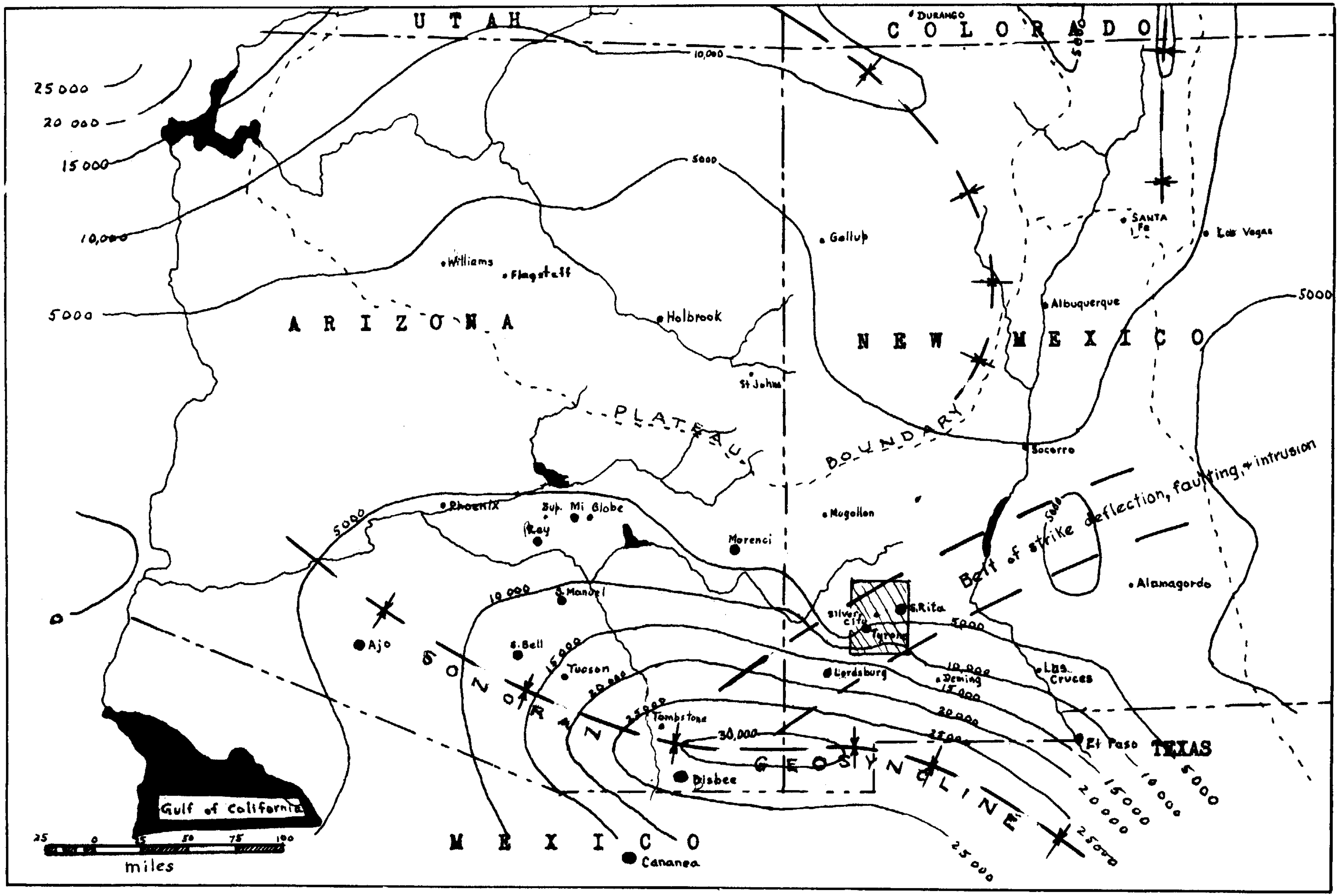


108°07' 30" Compiled by W.R.Jones
June, 1953

Geology by R.M.Hernon, W.R.Jones, S.L.Moore, S.G.Lasky, 108°00'
T.G.Lovering, A.F.Shride, G.S.Koch,Jr. 1931, 1948-52

GENERALIZED GEOLOGIC MAP OF THE SANTA RITA QUADRANGLE, NEW MEXICO

1 ½ 0 1 mile



Index map showing location of Silver City 30-minute quadrangle in relation to the Sonoran geosyncline and a belt of strike deflection, faulting, and intrusion.

ISOPACH MAP AFTER McKEE, 1951
Showing combined thickness of rocks of Paleozoic and Mesozoic age.

FORMATIONS IN THE SANTA RITA QUADRANGLE, NEW MEXICO
(Modified after Lasky and Hoagland, 1948)

System	Series	Formation	Character	Thickness in fe
Quaternary	Recent and Pleistocene	Alluvium	Unconsolidated sand, gravel, and clay partly filling desert flat south of the district; stream filling; and loose gravel veneer on hills and benches.	Variable
	Unconformity			
	Miocene (?)– Pliocene	Mimbres conglomerate	Consolidated and deformed sand, gravel, silt, and clay, with interbedded basalt flows in the desert flat south of the district, and north and east of the quad-rangle.	1,000 ±
	Unconformity			
	Miocene (?)	Lava flows	Flows of basalt; contain iddingsite and/or olivine; locally interrupted by rhyolitic tuff.	850 +
Tertiary	**Unconformity**			
	Miocene (?)	Rhyolite tuffs	Rhyolite – quartz latite crystal tuffs interrupted locally by sand underlain by a pitchstone flow.	0 – 700
	Unconformity			
	Miocene (?)	Lucky Bill formation	Gravel, sand, and pumiceous tuffs; well-sorted and stratified in places.	0 – 600
	Miocene (?)	Rubio Peak formation	Gravels and pumiceous tuffs with interbedded flows of andesitic basalt.	0 – 600
	Unconformity			
Tertiary	Lower Tertiary	Wimsattville formation	Basin-filling gravel, sand; restricted to Wimsattville basin.	1,000 ±
	Unconformity			
— ? —	Upper Cretaceous- Lower Tertiary	Andesite breccia	Volcanic breccia, tuff, with some sandstone, shale, and pumiceous tuff.	Variable 0 to severa hundred fee
	Unconformity			
Cretaceous	Upper Cretaceous	Colorado formation	Lower 200 feet black shale with 20' sandstone bed 80' from base, locally. Upper part sandstone and shale.	1,000 +
	Upper (?) Cretaceous	Beartooth quartzite	Quartzite with minor sandstone and limy and shaly beds locally.	66 – 140

FORMATIONS IN THE SANTA RITA QUADRANGLE, NEW MEXICO (continued)

System	Series	Formation	Character	Thickness in feet
	Unconformity			
Permian (?)		Abo formation	Red shale with thin beds of limestone and limestone conglomerate.	0 – 200
Pennsylvanian		Magdalena group (Syrena and Oswaldo formations)	Chiefly limestone with interbedded shale. (Syrena). A persistent shale unit, 40 to 140 feet thick lies above the Oswaldo formation (400 feet). A persistent 20 foot shale at the base of the Oswaldo is known locally as the Parting shale. This group is host for iron ores at Hanover, Santa Rita, and Copper Flat; zinc ores at Hanover, Copper Flat and Bayard; and iron and zinc ores at Copper Flat.	800
	Unconformity			
Mississippian		Lake Valley limestone	Upper 100 to 163 feet is white crinoidal limestone. Principal host rock of district. Lower part is gray limestone with some tan marly and shaly limestone beds.	300 – 400
Devonian	Upper Devonian	Percha shale	Black fissile shale overlain by 100 feet of gray shale with limestone nodules in upper part.	230 – 315
	Unconformity			
Silurian		Fusselman limestone	Cherty dolomite	Indefinite; (included in Montoya limestone)
Ordovician	Upper Ordovician	Montoya limestone	Dolomite and cherty dolomitic limestone. Sandstone at base.	500 + (includes Fusselman)
	Lower Ordovician	El Paso limestone	Dolomite and limestone, sandy in lower part.	500 ±
Cambrian	Upper Cambrian	Bliss sandstone	Glauconitic and hematitic sandstone and sandy limestone.	145
Precambrian			Granite, gneiss, schist and greenstone	

Thickness of most formations is variable for three reasons: (1) Some beds were eroded before deposition of next younger beds; (2) near intrusives, beds were stretched and thinned by plastic flow; (3) gravels, tuffs, and flows are thickest where they filled depressions in the erosional surface at the time of deposition.

rocks have proved to be consistent in age relations, and these, along with structural events, provide convenient curtains by which to subdivide geologic time, Inevitably, some isolated or aberrant types of igneous rocks were mapped which cannot be fitted satisfactorily into the sequence. Also some masses are doubtfully assigned because their characteristics are greatly obscured by cover, alteration, or shearing.

The older igneous rocks are much more consistent in character than the younger ones. This is believed to result from the progress of erosion — —that is, the later igneous rocks were intruded under progressively shallower depths of cover. Border breccias and associated pebble dikes are much more common along or near the later intrusives than along the earlier ones.

The small scale of the generalized geologic map required the grouping of several types of igneous rocks of several known ages. From youngest to oldest the major groups shown on the map and some of the types included in the groups, but not shown on the map are:

Groups shown on map	Types included
Omitted from map	Flow-banded felsitic rhyolite plugs and dikes; associated with Miocene (?) volcanic rocks in the region. Basaltic dikes with olivine and/or iddingsite; associated in space and time with Miocene (?) volcanics.
Tertiary, later dikes and plugs	May be subdivided into two subgroups each of which includes 3 or 4 rock types showing varying age relationships. One subgroup characterized by low quartz content, the other by higher quartz content. Of intermediate composition; breccia borders common; fluxion banding common; this group cuts Wimsattville basin filling. May include some Tertiary intermediate-age dikes, which they resemble.
Wimsattville Basin Filling	
Tertiary, intermediate age dikes	Includes at least two textural varieties of salic quartz monzonite dikes. Intruded prior to the filling of the Wimsattville basin.
Granodiorite and quartz monzonite porphyry dikes	Includes granodiorite dikes younger than the stocks, and probable apophyses of the stocks; and the distinctly younger quartz monzonite dikes.
Granodiorite and quartz monzonite stocks	The Santa Rita, Fierro-Hanover, and Copper Flat stocks all of which are actually composite bodies.
Gabbro plug and basic dikes	Augite and pigeonite andesite porphyry dikes Augite-biotite andesite porphyry dikes Augite diorite porphyry dikes Orthoclase – gabbro plug in northwest corner of the quadrangle. Note: – None of this group has been found south of the Barringer fault.
Quartz diorite sills, laccoliths	Albite-quartz porphyry Pyroxene-hornblende diorite porphyry Earlier quartz diorite Later quartz diorite Hornblende porphyry

Mode of intrusion

The earliest igneous intrusives, members of the quartz diorite group, were intruded as sills and laccoliths in the sedimentary cover. The scarcity of dikes of this group south of the Barringer fault suggests that few continuous crosscutting fractures existed south of the fault during the early stages of igneous activity. Several dikes of later quartz diorite, and hundreds of basic dikes of somewhat later age, are found north of the fault. Evidently the earliest development of crosscutting fractures occurred north of the Barringer fault.

As stated by Lasky (Lasky and Hoagland, 1948),

> "the sills and laccoliths dilate the formations in which they lie, so that if they were removed, the sedimentary section would be complete and uninterrupted. The rocks above them are lifted into folds that conform to the outlines of the intrusives. .... almost invariably the sills and laccoliths are intruded either within or along the bottom or top of a shale bed."

The sills are broadly discordant, and locally break abruptly across the bedding.

At the end of this episode of intrusion the thickness and competency of the sedimentary section was materially increased. Between subsequent episodes of intrusion fractures and faults developed and served as channelways for the magmas and hydrothermal solutions. Major development of the fault-fracture pattern took place prior to and during intrusion of granodiorite.

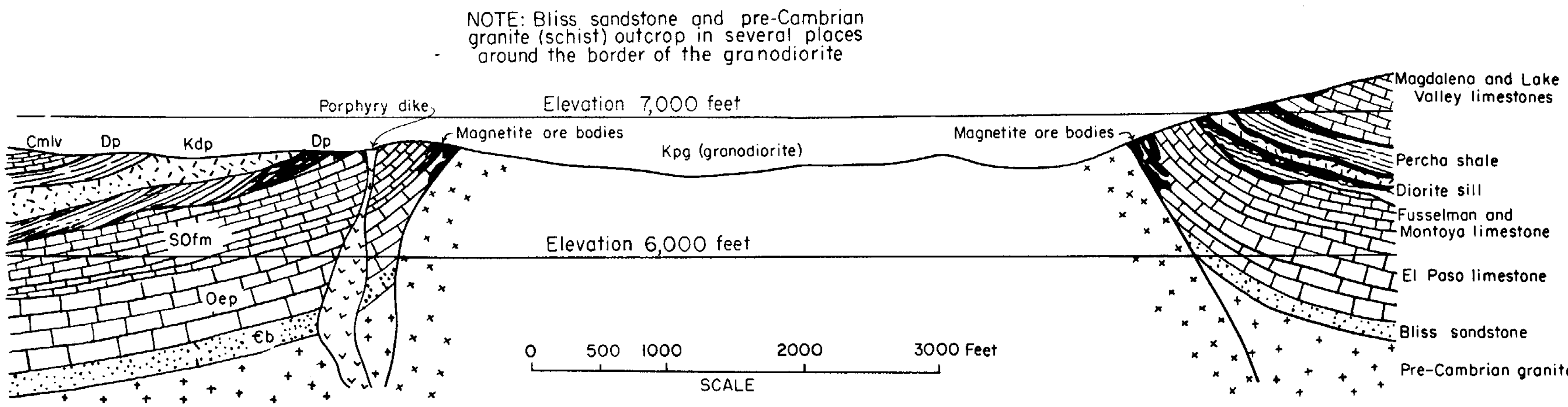
Of the three granodiorite-quartz monzonite intrusive masses, the Santa Rita mass and the northern three-fourths of the Hanover-Fierro mass have orthodox stock like shapes. So far as can be seen, they are steep-walled, crosscutting masses. The Copper Flat intrusive and the south lobe of the Hanover-Fierro intrusive contract with depth. It is obvious that the host beds were pushed aside forcibly to make room for the outward and upward expansion of these intrusive bodies. Lasky and Hoagland (1948) states "the Copper Flat stock - - - is a small body about 2000 feet long and 1000 feet wide at the surface, but mining operations have shown that a good part of this mass has a floor within a few hundred feet of the surface, and that downward it breaks into dike-like and chimney-like roots." Around most of the margin of the mass the beds are crinkled into a series of anticlines and synclines whose axes are concentric to the margin of the stock. Similar relations are found around the south lobe of the Fierro-Hanover stock, (Schmitt, 1939). The northern three-fourths of the Fierro-Hanover stock appears to be a normal steep-walled, crosscutting mass, but a possible upward expansion may have been completely removed by erosion.

The Santa Rita stock is irregular in plan; the major irregularities show relationship to pre-existing fracture zones of northwest, northeast, and east trends. These sets of fractures, projected, intersect in the vicinity of the south pit of the Chino mine. The intrusive mass probably made its way up this near vertical zone of intersecting fractures. The greatest dimension of the mass, so far as it can be determined, trends north-northwest within a mile-wide belt characterized by northwest fracturing, faulting, and shearing. A long, complex history of dike intrusion followed the emplacement of the stocks. Most of the dikes are irregular in plan and in section. Many intrude steep echelon fractures and end abruptly for no apparent reason. Others were injected along sets of linked faults and when viewed in plan or section have grotesque shapes as was pointed out by Lasky (1936, p. 36, fig. 4).

Many of the later dikes have chilled borders ranging from an inch to several feet in thickness. Where exposures are poor, or where dikes are narrow, chilled border rock is easily mistaken for a separate injection. Actually, many fractures have been opened repeatedly so that composite dikes are common. The brecciated walls of the younger dikes imply that they were intruded with explosive violence under near surface conditions.

Structure

As may be seen on the generalized geologic map of the Silver City region, the Santa Rita quadrangle lies on the northeast flank of a broad shallow syncline whose axis extends northwest from Hurley toward Pinos Altos. The northeast homoclinal dip of the strata in the Silver City and Lone Mountain Ranges marks the southwest flank of the syncline. Locally the regional syncline is modified by several domes, anticlinal arches, and tight folds related to emplacement of the intrusive rocks, and by flexures related to faulting. There is no evidence within the



GEOLOGIC SECTION THROUGH MAIN INTRUSIVE, FIERRO, NEW MEXICO

Taken from: Kniffin, L.M.; U.S. Bureau of Mines Inf. Cir, 6361, Figure 2, 1930.

quadrangle of folding resulting from regional tangential forces.

Faulting is a conspicuous type of structural adjustment in the Santa Rita quadrangle. Most of the faults have throws of less than 300 feet, but a few faults have throws ranging from 500 to 1600 feet. The displacement on the Mimbres fault, the most prominent fault of northwest strike, is undetermined but is probably large. Nearly all the faults have displacement of normal type, but inclined to horizontal mullion structure in some faults suggests that a large proportion of the displacement is strike-slip. Wedge-shaped graben and horst blocks are common in the southern half of the quadrangle. The measured displacement on many faults is the result of recurrent movement. The movement along the Groundhog fault illustrates what may well be the typical history of adjustment along major faults in the area. According to Lasky and Hoagland (1948) pre-granodiorite movement gave a throw of 1000 feet; post-granodiorite, pre-ore throw amounted to 250 feet; and post-volcanic throw was 330 feet.

The fault and fracture system includes both northeast-trending and northwest-trending sets, but the northwest-trending set, except for the isoloted Mimbres fault, is largely restricted to a mile-wide belt of northwest trend that embraces the Santa Rita stock. In the area northwest of the south pit of the Chino mine, the fault pattern is conjugate in plan with both sets, and suggests simultaneous origin of the two sets in this area.

A plot of the strike of the principal faults in the quadrangle shows that most of them strike in the northeast quadrant; only a few strike in the northwest quadrant. Of those which strike between north and east, about 40 percent dip west or northwest, and about 60 percent dip east or southeast. The principal northwest-trending fault dips northeast.

The elliptical area near Hanover underlain by the Wimsattville formation is a steep-walled craterlike hole that appears to have been formed in post-ore time between intrusion of the intermediate age Tertiary dikes and the later Tertiary age dike-groups. The rocks of Mesozoic and Paleozoic age that were once there were either blown out and scattered over the region or they sank more than 1000 feet when magma was withdrawn from beneath the elliptical area.

Three large areas of irregularly brecciated country rock occur within the quadrangle. Two of the breccia areas are intricately intruded by granodiorite, and the third, north of the Barringer fault, contains angular fragments of the next younger igneous rock.

The history of faulting and fracturing is summarized in the following table, in which structural events are related to the known sequence of igneous rocks, with the oldest event at the bottom and the youngest at the top. The same relationships are shown diagrammatically on the generalized diagram of igneous rock sequence and relations of structural and mineralization events.

Alteration and Mineralization

Pyrometasomatic and hydrothermal alteration, in places obscured by intense secondary alteration, extends across the quadrangle, from the Barringer fault south and southeastward, in a broad belt that includes the Fierro-Hanover and Santa Rita stocks. Prongs of intensely altered rock project from this main belt of alteration along the major fracture zones. One such prong follows the Barringer fault; another follows the Lovers Lane – Groundhog fault system; and still another follows the Copper Glance fault. The kinds of alteration include: silication of limestone; recrystallization of limestone with or without bleaching; alteration of bleaching type in non-carbonate rocks; silication; hornfelsing of shale and shaly sediments with some carbonate content; and, associated with some of the foregoing, introduction of iron as magnetite and/or pyrite, as well as the introduction of other substances. Many cubic miles of rock have been affected by these types of alteration.

The largest areas of severely altered rock surround the three granodiorite stocks. Smaller metamorphosed masses are associated with granodiorite dikes. Around the stocks, the metamorphism appears to have taken place after at least partial freezing of the intrusion, for garnet veins in places cut the granodiorite; likewise garnet replaces the post-stock granodiorite dikes, and much epidote shows control by fracturing within granodiorite. These observations do not preclude the possibility that some alteration accompanied the intrusions; they do indicate conclusively however, that alteration continued long after the exposed parts of the stocks and dikes solidified. Little if any effects of contact metamorphism have been noted along sill and laccolith contacts, or along Tertiary dike or plug contacts.

Summary of faulting and fracturing, Santa Rita quadrangle, New Mexico

IGNEOUS ROCK SEQUENCE	STRUCTURAL EVENTS AND REMARKS
	Very minor faulting that affects cemented older alluvium
	Faulting that displaces the Mimbres conglomerate; probably a part of the rejuvenation events which were followed by destruction of the Bayard surface.
Miocene (?) volcanism	Punctuated by several periods of renewed minor faulting. Those older than the basalt flows may correlate in part with reopenings that punctuate intrusion of intermediate and later Tertiary igneous rocks below.
Upper Tertiary intrusives	Several ages of igneous intrusion alternating with renewed minor faulting and fracturing.
	Mild reopening; strong sheeting of northwest strike west of Chino mine was renewed. Development of Wimsattville craterlike depression.
Intermediate age Tertiary intrusions	
	Mild renewed fracturing and faulting; locally strong.
Lower Tertiary or Upper Cretaceous intrusion of quartz monzonite porphyry	
	Widespread reopening and shattering; formation of some new breaks.
Granodiorite dikes	
	Widespread reopening of older breaks and formation of new ones.
Granodiorite stocks and apophyses.	
	Essentially complete development of the fault and fracture pattern.
Gabbro plug, basic dikes and andesite breccia.	
	Intrusion of orthoclase gabbro plug accompanied – and/or preceded, and followed – by radial fracturing. Barringer fault probably in existence prior to these intrusions.
Later quartz diorite	
	Very weak further development of the fracture pattern; faulting probably very minor.
Earlier quartz diorite porphyry.	
	Weak local development of the northeast and northwest-trending fracture-fault system; through-going breaks apparently very few in number.

The minerals produced by the alteration are clearly related to the chemical composition of the rock affected, especially its aluminum and magnesium content, and to the distance between the rock and the intrusive, or the rock and the main channelways.

Around the Copper Flat intrusive Lasky separates the metamorphic halo into three zones: (1) an inner garnet-hornfels zone with hematite, magnetite, and zinc bodies; (2) an adjoining marble zone; and (3) an outer, somewhat discontinuous actinolite-tremolite zone.

Around the south lobe of the Fierro-Hanover intrusive, where pure limestone and shaly limestone of low magnesium content predominate, garnet, salite, magnetite, tremolite, and epidote were formed. Schmitt (1939) demonstrates that the alteration was accomplished by large-scale addition of silica and iron with some addition of aluminum and manganese, and large-scale loss of carbon dioxide and lime. Most of the silica added may have been derived from development of epidote, chlorite, and sericite in the aluminous rocks (Schmitt, 1939). Around the margins of the northern part of the Hanover-Fierro intrusive, where magnesium-rich limestones and dolomites predominate, the products of alteration are wollastonite, serpentine, abundant magnetite, and tremolite. Actinolite is sparse, and garnet is practically absent. The aluminum content of the rocks is the controlling factor favoring the formation of epidote (Schmitt, 1939), and thus epidote is much more abundant in shale and igneous rocks.

The bleaching-type alteration, characterized by extensive sericitization, argillization, and silicification, apparently accompanied large-scale pyritization. Because it destroys epidote and chlorite it is believed to be later. The bleaching-type alteration is best developed in and west of the Santa Rita stock and along parts of the Barringer fault. Some of the bleaching effect is due to the development of clay minerals, but the proportion of the clay that is of hydrothermal origin has not been determined. There can be little doubt that much of it resulted from percolation of acid meteoric waters.

Certain silicates, salite-hedenbergite, ilvaite, and rhodonite, are typically associated with zinc ore bodies and appear to belong to a slightly later phase of alteration than garnet. Salite has for many years been considered a guide to zinc ore (Schmitt, 1939).

Copper, in the form of chalcopyrite, is spatially associated with areas affected by the bleaching-type alteration, but, in detail, chalcopyrite is abundant in only slightly altered rock; it is commonly associated with biotitized hornblende.

Epidote is a common secondary constituent in all the older rocks through the quartz monzonite porphyry that was intruded next after the granodiorite dikes. Small amounts of epidote have been found in the borders of still later intrusives but only where previously epidotized host rock is present. Some of this epidote in later intrusives is in inclusions, but some has crystallized where found.

Mild to moderate alteration, characterized by calcitization, sericitization, chloritization, and weak kaolinization and pyritization, apparently followed each succeeding episode of Tertiary intrusion. The later Tertiary group of dikes are unaltered in many places, but much of the Bull Hill intrusive is severely kaolinized.

Metalization followed pyrometasomatic alteration, as shown by the replacement of garnet, epidote, salite, or hedenbergite by the sulphides of zinc, copper, lead, and iron. In general the minerals containing ferric iron were formed early, but, as time progressed, the minerals containing ferrous iron formed in silicate-corroding solutions (Schmitt, 1939). Disseminated chalcopyrite is associated spatially with pyritization and bleaching-type alteration, but the detailed sequence is in doubt.

Ore Deposits

In general, the major ore deposits of the Santa Rita quadrangle are related spatially to the belt of intensive alteration and its apophyses described above. Minor deposits of silver, and of manganese, fall outside the limits of severe alteration. The volume of valuable minerals introduced is only a fraction of a percent of the volume of non-economic alteration minerals, many of which were formed in place with but minor additions from migrating elements.

The ore deposits of the district may be classified into the following types:

1. Magnetite deposits near the contact of the Fierro-Hanover stock.

2. Replacement deposits of zinc with variable amounts of lead and copper.

a. Nearly lead-free replacement zinc deposits around the south lobe of the Hanover stock, north and northwest of the Santa Rita stock, and along the Barringer fault close to the Hanover stock.

b. Replacement deposits of zinc with lesser amounts of lead and copper in a broad belt extending southwest from Hanover, and along the northeast extremity of the Barringer fault.

3. Vein deposits of zinc, lead, and copper in the southeast quarter of the quadrangle.

4. Secondarily enriched, disseminated copper deposits in and around the Santa Rita stock and in sheared and brecciated rocks along the Barringer fault.

5. Replacement bodies of silver in the Fusselman limestone at Georgetown. In addition, there are small scattered replacement bodies of manganese in the late Paleozoic rocks close to the Barringer fault; also enriched vein-gold and placer-gold deposits near the village of Vanadium.

The lead-zinc ratio increases along the main ore channels extending south and southeastward from the deposits located around the south lobe of the Fierro-Hanover intrusive. From observations of hand specimens and of district-wide relationships, either copper was deposited later than zinc or copper deposition continued much longer than zinc deposition. Little, if any zinc occurs within a zone 500 feet wide around the Santa Rita stock. Either it was never deposited in the stock area or it was flushed out by later hydrothermal solutions and redeposited farther out from the center of copper mineralization.

Certain formations were evidently more favorable to replacement. The upper 100 to 163 feet of the Lake Valley limestone, a pure crinoidal member, locally known as the Hanover limestone, was an especially favorable host. Other favorable hosts include the limestone of Pennsylvanian age above the so-called Parting shale member, and limestone below the Hanover. Regionally the Fusselman limestone, lying below the Percha shale, has yielded many rich bodies of silver and lead ore. This zone has been but little explored in the Santa Rita quadrangle outside of the Fierro iron ore district. Evidently chalcopyrite was less selective in its choice of a host, for it is found in all rocks present at the time of its deposition. Good descriptions of the vein, replacement, and disseminated ore bodies of the district may be found in the literature and will not be repeated here.

Interrelation of important geologic events

The interrelation of igneous intrusion, structural development, alteration, and metalization within the Santa Rita quadrangle is shown on the chart "Generalized diagram of igneous rock sequence and relations of structural and mineralization events."

The diagram divides geologic time by means of the Upper Cretaceous or lower Tertiary, and Tertiary igneous rocks, whose sequence has been established. The rocks shown are the major types present in the Santa Rita—Fierro—Vanadium area. The vertical lines that represent these intrusives are not necessarily spaced to indicate length of time but rather to accommodate the other data represented.

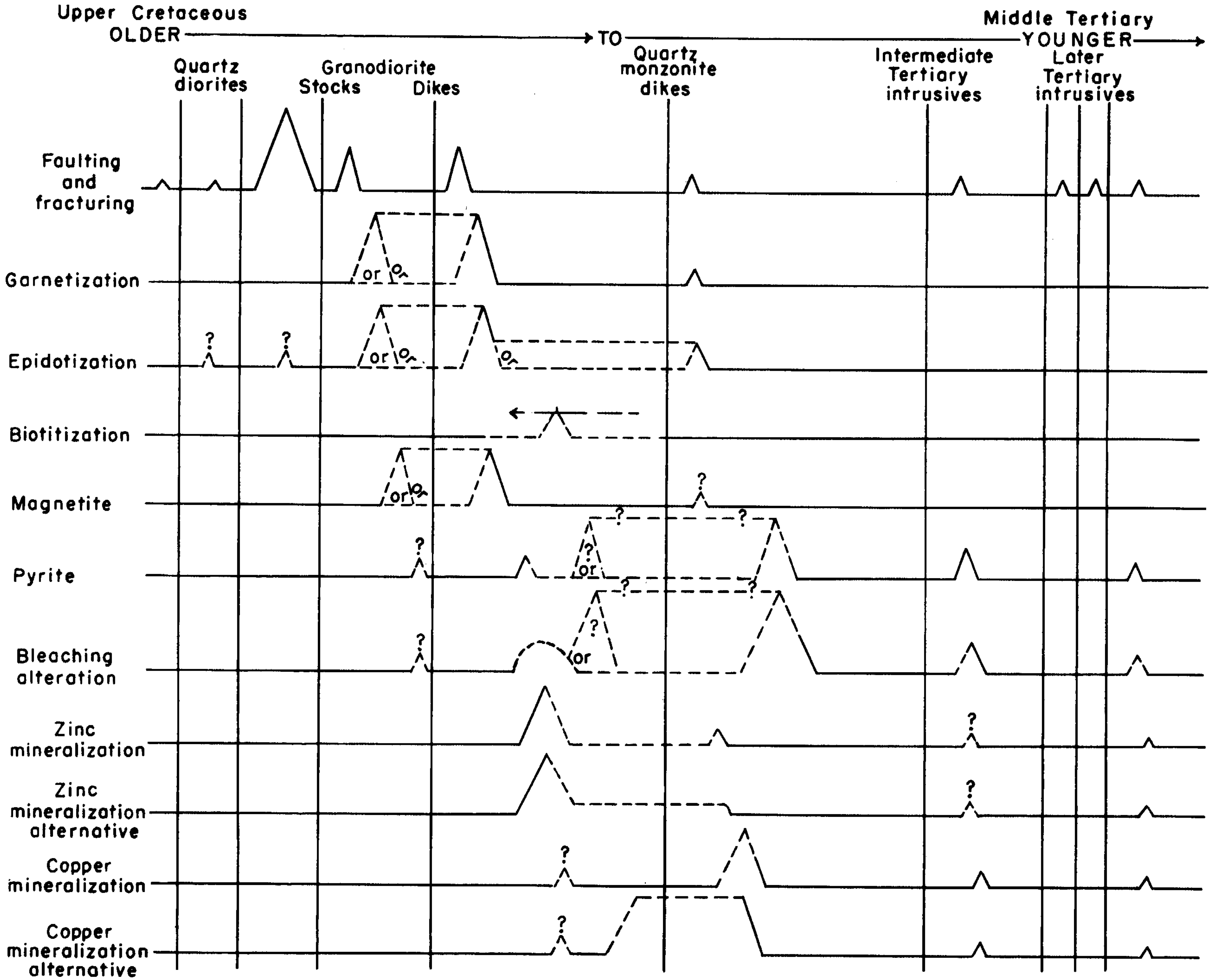
The long straight portions of horizontal lines opposite processes represent zero activity and lack of information. The peaks that rise from any one line show known or inferred activity of the process represented by that line. Parts of such peaks shown in solid line are well-supported by direct evidence. Dashed portions represent indecisive evidence or evidence that cannot be interpreted satisfactorily. The fact that one part of a peak exists necessitates that the other part also exist, even though its exact position is not known.

The difficulties encourtered in preparation of this diagram, and its deficiencies, are similar to those of any other paragenetic diagram. It is generally much easier to determine when a process ceased than when it began. It is necessary to give weight to both positive and negative evidence. The diagram can only partly indicate the quality of evidence. Several alternate representations of evidence can be made in certain portions of the lines. The extreme alternatives, or those that seem to be favored by the evidence, are shown.

It is impossible to indicate the detailed evidences in this paper. In general, the diagram is based on physical relations between minerals, minerals and rocks, minerals and structures, rocks and structure, and rocks and other rocks.

The line that represents faulting and fracturing is reliable; more detail could be added. The least reliable line is that representing pyritization, because of the "persistent" nature of pyrite. Brief

GENERALIZED DIAGRAM OF IGNEOUS ROCK SEQUENCE AND RELATIONS OF STRUCTURAL AND MINERALIZATION EVENTS



remarks regarding the processes follow.

Garnetization and epidotization may have recurred as indicated or may have been active processes only after solidification and fracturing of the granodiorite dikes. The evidence is clear that these processes followed intrusion and probably solidification of the hoods of stocks.

Biotitization is apparently restricted to the area of disseminated copper mineralization. It affects granodiorite stock rock and the younger granodiorite dikes, but so far as known does not affect the next-younger quartz monzonite dikes.

Representation of magnetite deposition, at least in volume, is subject to the same uncertainties as representation of garnetization.

Bleaching alteration is parallel with and closely associated in space and probably in time with pyritization.

Zinc mineralization is shown by two alternatives, both of which show large-scale introduction of zinc after reopening of the granodiorite dikes. The subjective element in such interpretation is large. Zinc mineralization is shown in this manner because zinc ore is in many places clearly related to reopening along and in granodiorite dikes; but so far as known, it is not related to reopening along and in the next-younger quartz monzonite porphyry dikes.

Copper mineralization is shown by two of several possible alternatives. Both show large-scale copper mineralization after intrusion of quartz monzonite porphyry, because the quartz monzonite porphyry contains about as much of the primary mineral, chalcopyrite, as does granodiorite where the two rocks are about equally shattered. Both alternatives show the main copper mineralization after the main zinc mineralization because of described relations (not decisively interpretable) to quartz monzonite porphyry, the paragenetic relations of chalcopyrite and sphalerite in veins, and the absence of zinc so far as known in the rocks intensely mineralized by disseminated chalcopyrite.

GEOLOGY OF THE SANTA RITA AREA

by
G. J. Ballmer*

Introduction

The distribution of the rocks at Santa Rita presents a rather complex picture. Sediments, ranging in age from the late Paleozoic through the Upper Cretaceous, have been faulted, intruded, altered and generally "discombobulated" to such an extent that the present picture is somewhat formidable. This sedimentary-igneous complex later was further complicated by intrusion of dikes, faulting, and final covering of all of the area by Tertiary flows.

Geologic History

Following the deposition of the sediments several thick and numerous thin sills of quartz diorite porphyry of two ages were intruded into the limestones and shales and sandstones of the Upper Paleozoic and Upper Cretaceous. Considerable faulting followed and may have accompanied these intrusions. The sills in the Paleozoic limestones, in general, are much thinner than those in the upper Cretaceous which may attain thicknesses of several hundred feet. The former also are most persistent in their horizons and one, occurring about 90 feet above the base of the Pennsylvanian, has locally been termed the "marker sill" because of its remarkable persistence.

Subsequent to the intrusion of the sills, the sedimentary and igneous rocks were intruded by a large granodiorite porphyry stock which was forcibly pushed through the sediments causing rather steep dips at the contacts. This stock sent out dike-like fingers or apophyses, at various points, and was itself intruded by granodiorite porphyry dikes of a slightly later age. Mineralogically, not a great difference exists between the rock of the stock and that of the sills. One difference, however, is the coarseness of the stock rock and the comparatively fine-grained texture of the sill rocks, particularly the thinner ones. The stock and dikes intruded planes of weakness, as faults, that originated shortly after intrusion of the sills. Movement along these various faults has taken place at several intervals up until very recently.

* Superintendent of Mines, Chino Mines Division, Kennecott Copper Corp.