GEOLOGIC STRUCTURE OF THE SAFFORD DISTRICT, ARIZONA

by

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Abstract

The Safford mining district is restricted to a 15-mile-long, northwest-trending belt of Eocene igneous rocks along the southwestern flank of the Gila Mountains in Graham County, Arizona. It includes two major and two smaller porphyry copper deposits and is one of the largest districts in the Southwest as measured by the amount of copper metal.

Premineral andesitic extrusive rocks, including bedded and crystal tuffs emplaced in volcanic vents, have been intruded by a quartz diorite stock, a series of latite and quartz latite dikes, and several small quartz monzonite porphyry intrusions. The rocks are comagmatic and yield K-Ar age dates ranging from 58 to 53 m.y. The copper mineralization is directly related to the quartz monzonite bodies.

The principal structural features of the district include faults parallel to the elongation of the premineral outcrop and northeast to east-northeast structures that controlled mineralization at the individual deposits. The northwest-striking faults include the Butte fault, which extends the full length of the district and has as much as 4,000 feet of vertical displacement. Other northwest faults have offset the Sanchez deposit and controlled the distribution of oxide and supergene ore at the Kennecott deposit. These faults were presumably controlled by the same regional structures that caused the rough alignment of the porphyry copper deposits in the district.

The northeast-striking structures include dike swarms and mineralized fractures; faults have been difficult to map because of the lack of marker units in the andesite. These northeast-striking faults have no more than a few hundred feet of vertical displacement measured at the base of the postmineral volcanic rocks. They have been in existence since the period of mineralization, however, and may have had as much as 1,500 to 2,300 feet of vertical displacement since the intrusion of the quartz monzonite porphyry stocks.

Introduction

The Safford, or Lone Star, mining district is in Graham County in southeastern Arizona about 95 miles northeast of Tucson and about 18 miles southwest of Morenci (Fig. 1). Four separate porphyry copper deposits occur within a narrow northwest-trending belt of Eocene igneous rocks along the southwestern flank of the Gila Mountains. The belt of premineral outcrop is about 15 miles long and a little over two miles wide at its widest part. The premineral rocks are covered by postmineral volcanic rocks to the northeast and are bounded by a major normal fault to the southwest (Fig. 2). The porphyry copper deposits include the very large Kennecott and Phelps-Dodge deposits, the Sanchez deposit held by Inspiration Copper and the small San Juan deposit. Production from the district to date has been limited to an intermittent leaching operation at the San Juan, but the Lone Star district, as measured by the amount of copper metal, is one of the largest districts in the southwest.

The district has been an area of active exploration for more than 20 years, but very little information has been published on it. This paper is a compilation of my mapping in the Kennecott area and in the northwest end of the premineral outcrop where Quintana Minerals had been working. The compilation also includes previous mapping by Kennecott and Bear Creek geologists, by other Quintana geologists who had worked in the district, and from a Master's thesis at the University of Arizona on the San Juan deposit (Blake, 1971). I have been given permission by both Kennecott and Quintana to publish this

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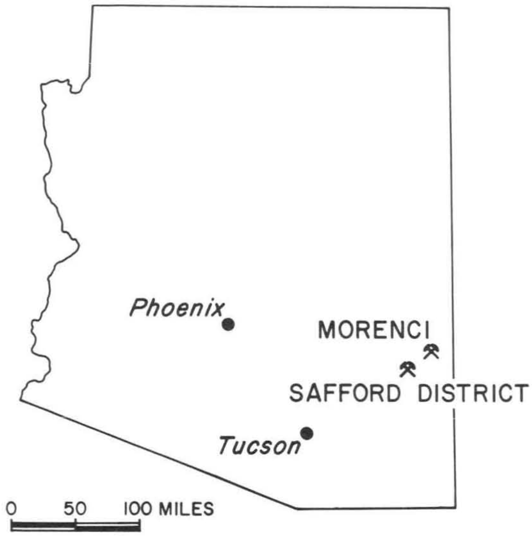

Fig. 1. Location map, Safford district

paper, but I am solely responsible for the structural interpretation.

Geology

The premineral rocks in the district include a thick sequence of andesite flows and agglomerates that have been intruded by the Lone Star quartz diorite stock, latite and quartz latite dikes, and several quartz monzonite porphyry stocks which are directly related to the porphyry copper mineralization. Mappable units within the andesite are rare. Drill holes up to 4,000 feet deep in the district have failed to reach the bottom of the sequence. This extreme thickness, together with the lack of obvious flow structures in most of the andesite, and the lack of a sharp contact between the andesite and the quartz diorite in drill core suggest that part of the andesite may have been formed as hypabyssal intrusions.

The quartz diorite forms several small plugs and dikes in addition to the Lone Star stock. It is not directly related to the copper mineralization anywhere in the district, although it does form the host rock of some of the primary mineralization in the Kennecott deposit. Several large xenoliths of Precambrian(?) granite and Cambrian(?) quartzite occur within the stock.

A near-vertical pipe of well-mineralized tuff is exposed near the center of the Kennecott deposit. The exposure is nearly 6,000 feet long in the northwest direction, and the tuff extends at least 4,000 feet to the northeast beneath the postmineral volcanic cover. It is exposed in the underground workings and in a single small outcrop behind the range front. On the surface and underground, the contact between the andesite and the mineralized tuff is nearly vertical. The tuff extends at least 2,000 feet vertically, but the nature of the contact between the tuff and the andesite is not known—no bottom has yet been found (Fig. 3). Part of the tuff is well-bedded with dips 30 to 50 degrees toward a common center, suggesting a collapse origin caused by removal of magma at depth. A much smaller outcrop of mineralized tuff occurs about a mile and a half to the southeast.

The youngest of the premineral rocks in the district are the stocks of quartz monzonite porphyry, each of which is associated with disseminated copper mineralization. Small quartz monzonite porphyry stocks are exposed at the San Juan and Sanchez deposits, and nearly identical rocks have been encountered at depth at both the Kennecott and Phelps-Dodge deposits. The smaller bodies of quartz monzonite porphyry at the Horseshoe mine and between it and the Sanchez deposit also contain minor copper mineralization. The four principal porphyry stocks occur as narrow near-vertical cylinders close to the center of each sulfide system.

The andesite and quartz diorite have both been cut by numerous latite and quartz latite dikes, dikes which could not be shown on the accompanying geologic map (Fig. 2). The dikes are generally 5 to 20 feet wide, and most occur as northeast-trending swarms. The two rock types can be distinguished in the field by the presence or absence of large quartz phenocrysts, and the two types are separated in time by the period of formation of the mineralized tuff. Dike fragments within the tuff consist only of latite, while only quartz latite dikes cut the tuff. An interpretation with possible exploration significance in the Safford district is that the latite dikes are related to the quartz diorite and that the quartz latite dikes are related to the quartz monzonite porphyry stocks.

The comagmatic origin of the premineral igneous rocks is indicated by the smooth curves on the variation diagram (Fig. 4). Whole-rock chemical analyses were made of unaltered andesite, quartz diorite, and dike rocks taken from the outcrop area southwest of the Kennecott deposit. This postulated comagmatic origin is supported by the narrow range (58-53 m.y.) of K-Ar age dates for the igneous rocks and a 53 m.y. date for the sericite at the Kennecott deposit (Robinson and Cook, 1966).

The postmineral volcanic rocks in the Safford district can be divided into three units: older andesitic basalt flows, a series of siliceous units including tuffs and rhyolite plugs, and younger basalt flows with thin interbedded tuffs. Tuff breccia at the base of the younger basalt flows contains fragments of leached capping. The postmineral units dip 10-15° NE., and this appears to be the total tilting of the district.

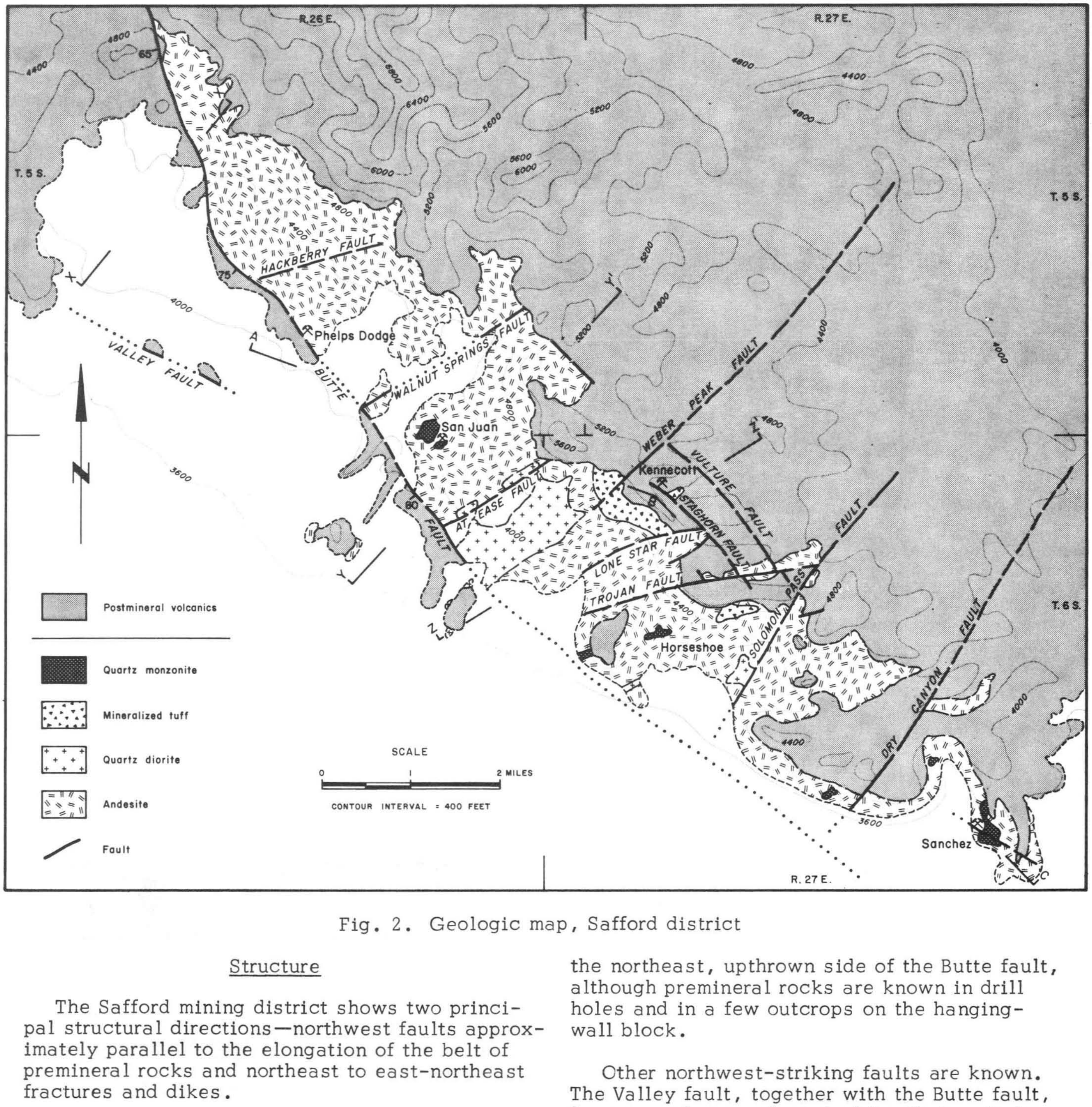

Fig. 2. Geologic map, Safford district

Structure

The Safford mining district shows two principal structural directions—northwest faults approximately parallel to the elongation of the belt of premineral rocks and northeast to east-northeast fractures and dikes.

The northwest-striking Butte fault is the most prominent structure in the district. It can be mapped from the northwestern end of the premineral outcrop as far south as the Lone Star stock and can be traced beneath the alluvium for the rest of the length of the district. It may well extend farther to the southeast to coincide with a conspicuously straight stretch of the Gila River south of Sanchez. The fault dips 65–80° SW. Exposure of premineral rocks are almost entirely restricted to the northeast, upthrown side of the Butte fault, although premineral rocks are known in drill holes and in a few outcrops on the hanging-wall block.

Other northwest-striking faults are known. The Valley fault, together with the Butte fault, forms a graben southwest of the Phelps-Dodge deposit, and the Carpenter fault has offset the quartz monzonite porphyry stock at the Sanchez deposit. The Staghorn and Vulture faults can be mapped in the postmineral volcanic rocks behind the range front. These two faults form a horst that accounts for the very small window of premineral tuff near the center of the Kennecott deposit; they also appear to have controlled the configuration of the oxidized and supergene portions of the deposit. The Vulture fault apparently extends farther to the

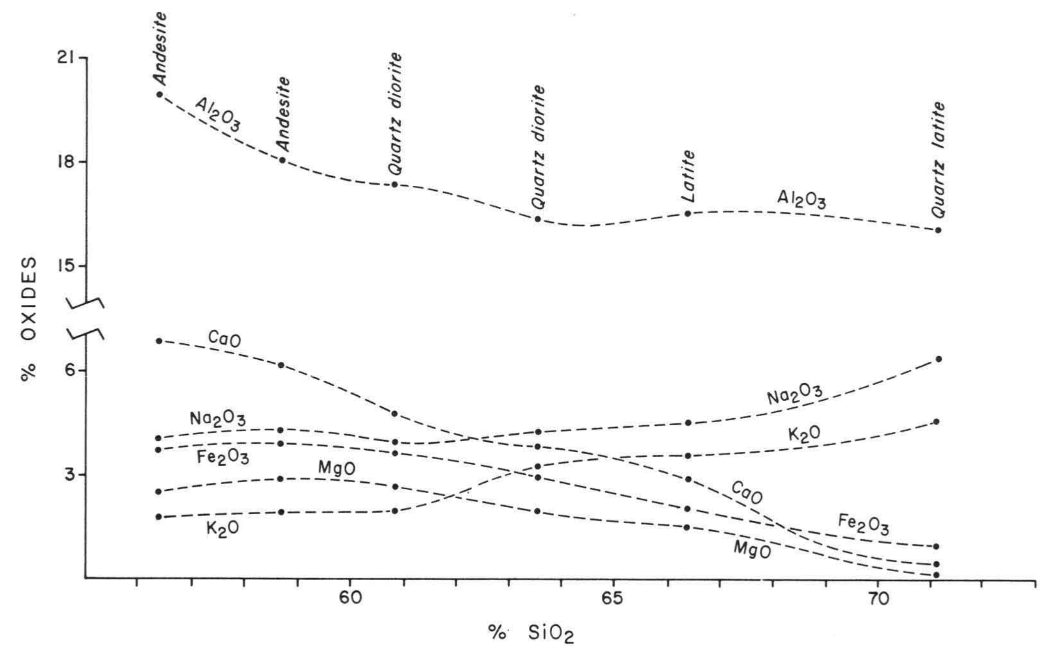

Fig. 4. Variation diagram for Eocene igenous rocks, Safford district

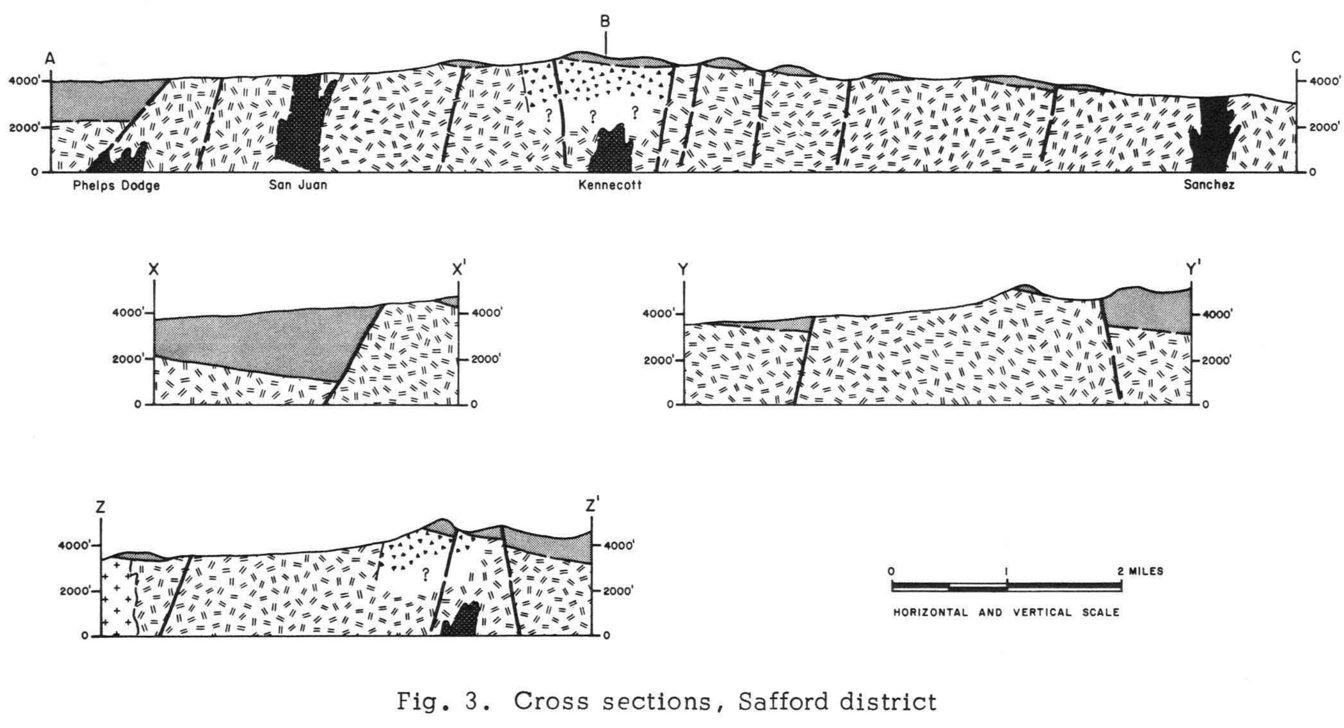

Fig. 3. Cross sections, Safford district

northwest and forms the boundary of the premineral outcrop northeast of the San Juan mine.

The amount of vertical displacement on the northwest-striking faults, all of which cut the postmineral volcanic rocks, is shown on cross sections X-X', Y-Y', and Z-Z' in Figure 3. The depth to premineral rock in each cross section is known accurately from drill holes.

Vertical displacement on the Butte fault ranges from more than 4,000 feet in the northwest to approximately 3,000 feet near the Lone Star stock. Slickensides on the fault plane and lack of drag or displacement of the dikes that are cut by the fault suggest that movement on the Butte fault has been primarily dip-slip. The fault displaces some portion of the Phelps-Dodge sulfide system, however, with an indication of left-lateral displacement. Vertical displacement on the other northwest-striking faults is no more than a few hundred feet. The premineral-postmineral contact marks the maximum measurable vertical displacement; in most of the northwest-striking faults, including the Butte, the displacement of marker units within the postmineral volcanic units is less than the maximum, indicating that the faults were reactivated during the period of postmineral volcanism.

Elongation of the premineral outcrop belt and irregular alignment of quartz monzonite porphyry stocks within the district are both thought to be a reflection of the same regional structures that controlled the northwest-trending faults. This regional structure is presumably an expression of the Gila discontinuity proposed by Titley (1976).

The most prominent structural features at the individual porphyry deposits strike northeast to east-northeast; these features include fractures and dikes, but few faults striking in that direction have been mapped. Stastistical treatment of mineralized fractures in three different areas of the district clearly shows the predominance of the northeast direction (Fig. 5). The Coyote Wash area is the northern end of the premineral outcrop north of the Hackberry fault. This northeast structural direction is a regional feature common in many of the Laramide stocks in Arizona (Rehrig and Heidrick, 1972).

Only a few northeast-trending faults have previously been mapped in the district because of the lack of marker units within the andesite. The Lone Star and Trojan faults were recognized because of obvious offset in the base of the postmineral volcanic cover and this displacement has been only a few hundred feet.

At least four other major northeast-striking faults cut the premineral andesite. These faults are not easily discernible but can be mapped on the basis of the following observations:

1. The Weber Peak fault is indicated by
   a. A very pronounced topographic alignment on both sides of the saddle
   b. Offset of the base of the postmineral volcanic cover.
   c. The straight collinear southeastern margin of the Lone Star stock.
2. The Dry Canyon fault is indicated by
   a. Offset at the base of the postmineral cover.
   b. The abrupt western termination of the window of premineral rocks in the back of the range.
   c. An obvious topographic alignment extending to the northeast.
3. The Solomon Pass fault can be inferred from
   a. A fault repetition of the postmineral tuff at the base of the volcanic cover at the head of the pass.
   b. The existence of the pass itself and a topographic alignment in both directions from the head of the pass.
   c. The straight eastern margin of the small quartz diorite plug east of the Horseshoe mine.
4. The Walnut Springs fault is indicated by
   a. A zone of intense fracturing mapped by Blake just west of the San Juan stock.
   b. The topographic alignment, marked by springs, that extends from the fractured outcrop near the Butte fault to the northern edge of the andesite outcrop.

Another probable northeast-trending structure, the Hackberry fault, occurs at Hackberry Spring and is marked by weak copper oxide mineralization along the bottom of a pronounced linear valley. Several other northeast-trending faults are thought to cut the Safford mining district, but they have not been accurately located.

The Weber Peak, Solomon Pass, and Dry Canyon faults can all be traced for several miles farther to the northeast on aerial photographs. They are parallel to and on strike with similar faults in the Morenci district (Langton, 1972); these faults at Morenci are not thought to be continuations of the Safford faults but again are a reflection of the regional stress field in southern Arizona.

The northeast-striking faults apparently controlled the present location of the porphyry de-

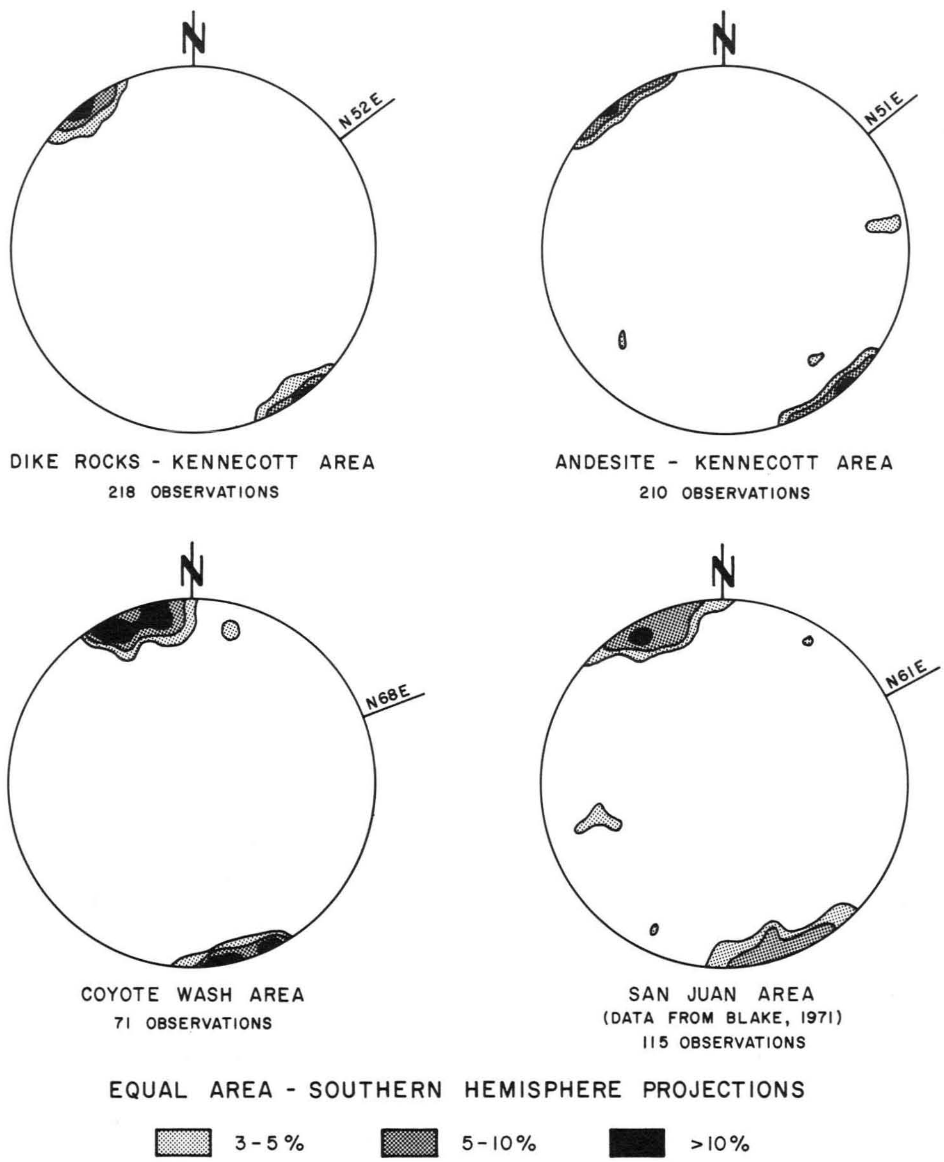

Fig. 5. Poles to mineralized fractures, Safford district

posits—both laterally and vertically. The vertical displacement during Tertiary time along these faults is only a few hundred feet as opposed to the 1,000 feet or more in Morenci. The amount of displacement since the formation of the porphyry copper deposits, however, is thought to be considerably greater than the amount that can be measured by the offset at the base of the postmineral cover. Copper mineralization along the Lone Star, At Ease, and Hackberry faults indicates the early existence of these structures.

The quartz monzonite porphyry stocks at the four porphyry copper deposits in the Safford district are nearly identical in both composition and texture. Assuming that these stocks were originally emplaced at approximately the same elevation, the total vertical separation between the Phelps-Dodge and San Juan deposits and between the Kennecott and San Juan deposits must be a minimum of 2,000 to 2,300 feet (Section A-B-C, Fig. 3). The minimum separation between the Kennecott and Sanchez deposits must be approximately 1,500 feet, and perhaps 1,800 feet, between the Kennecott deposit and the small plug of quartz monzonite porphyry at the Horseshoe mine. These vertical separations have been accounted for by late-Laramide or early-Tertiary movement along the various northeast-trending faults.

This hypothesis, based on the above assumption, is supported by the amount of movement along the Weber Peak fault indicated by the quartz diorite which is exposed at the surface west of the fault but is encountered only at a depth of about 1,500 feet in drill holes east of the fault. This is the same sense of movement that is indicated by the displacement of the overlying basalts and is suggested by the present elevations of the stocks at the Kennecott and San Juan deposits.

Lateral displacement along the northeast-striking faults cannot be definitely established, although it is suggested in the case of the Lone Star fault by an abrupt change in mineralization across the fault. A deep drill hole southeast of the fault encountered no appreciable sulfide mineralization for its entire length, although it is within 1,000 feet of the Kennecott deposit. Considering the extensive vertical range of mineralization in the sulfide systems in the district, it appears unlikely that such an abrupt change in mineralization can be accounted for by vertical displacement alone. Lateral displacement on some of the northeast-trending faults may therefore account for the lack of strict alignment of the four deposits in the Safford district.

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