Appendix A

Geology of the El Tigre District, Mexico

By R. T. MISHLER

GEOGRAPHY. To furnish a framework upon which to hang the geology, a brief outline of the geography of the surrounding country is necessary. The Tigre (or 'Lucky Tiger') mine is situated in the north-eastern part of Sonora, Mexico. The elevation is 5800 ft. Four miles north of El Tigre is Pilares de Teras, where are the Cinco de Mayo and Roy mines. Two miles north of El Tigre are the North Tigre and Santa Maria mines.

The district lies on the steep western slope of the Teras range of mountains. It is traversed by several deep canyons, all flowing west. The Bota is the deepest; it is three miles north of El Tigre and separates the Pilares and North Tigre districts. A branch of the Bota canyon has its source behind Tigre peak, the high mountain a mile east of the town.

At the north edge of the town is the Combination canyon; at the south edge is Espuelas canyon. The two join at the mill to form the head-waters of the Chinosos stream. A mile south of the town is the Tigre canyon. This is a branch of the Otates *arroyo,* which drains the west flank of the Teras range as far south as the Temblor mine. On the east side of the range the Pita canyon is the largest and deepest. The Pita stream flows east and empties into the Bavispe river near the town of San Miguel. Here the Bavispe flows north, between the Teras and Sierra Nevada ranges. Thirty miles north of El Tigre the river makes a loop around the north end of the Teras range and flows south, receiving the waters of the Bota, Chinosos, and Otates streams, before joining the Aros to form the Yaqui river.

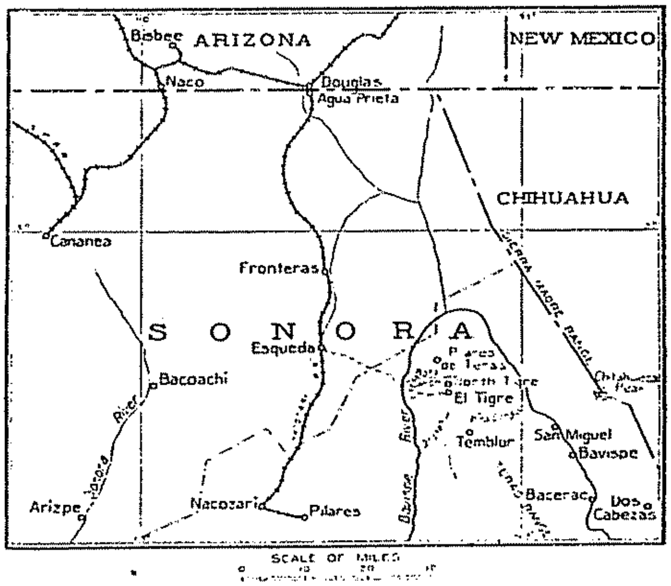
A rectangular area, including the principal claims of the Tigre Mining Company, was selected for detailed geological work. This area is roughly two miles long (north to south) by one mile wide. It extends from Palomitas canyon on the north to the South Tigre workings on the south; and from the mill on the west to the charcoal kilns on the east.

GENERAL GEOLOGY. During Mesozoic time the region about El Tigre was a rolling plain, covered with fluviatile fans fed by the erosion of the granite and limestone. Probably this surface was fairly close to sea-level, for only 20 miles west are thick beds of calcareous shale, which appear to have been deposited during the Mesozoic era.

Portions of the old surface are found at several places. The most conspicuous of these is the level bench above the dark rock on the hill north of the mill. The mill itself is on the granite, at a considerable distance below the Mesozoic surface; the old surface as well as all overlying strata having been trenched during recent time by the Chinosos stream. It is interesting to note that stratigraphically the mill is at the lowest point for miles roundabout.

The Tertiary era was an age of intense volcanic activity. The old surface was covered with successive flows of rhyolite and rhyolite tuff; the whole series aggregating 4000 ft. in thickness. This volcanic rock constitutes the main part of the mountains about El Tigre.

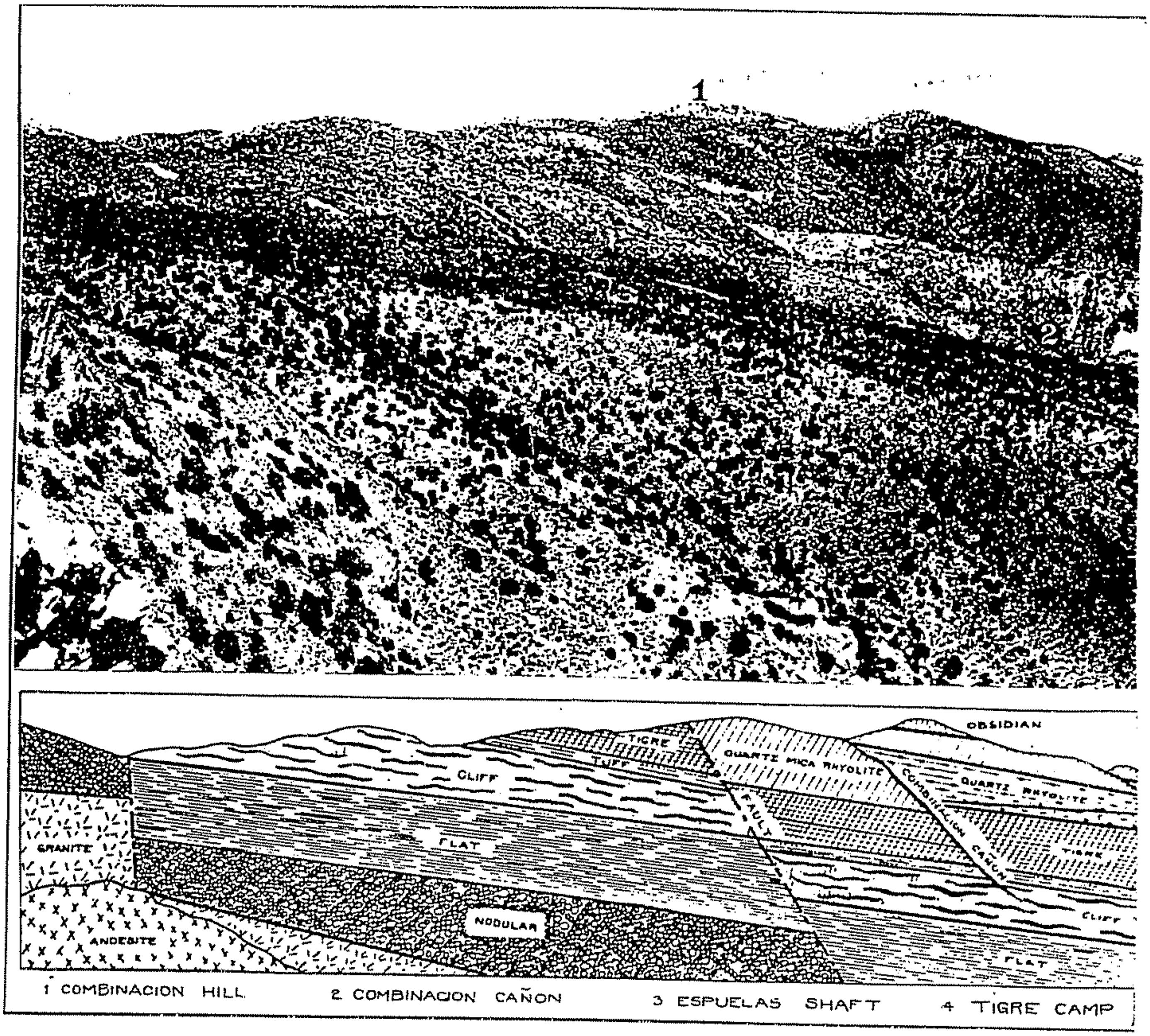
The lowest flow of lava, called locally the 'Nodular' formation, was laid down early in Tertiary time. After its formation, volcanic activities ceased for a while. Minor drainage systems were formed and an extensive lake was developed, with its centre where the town is now. The bed of the lake became filled with shale and thin layers of limestone. Later a new volcanic era was



MAP OF PART OF MEXICO

ushered in by showers of volcanic 'ash'. These formed beds of tuff, blotting out the inequalities caused by former erosion and covering the old lake-bed to a depth of 500 ft. Finally, a single flow of lava, 250 ft. thick, was poured out upon the tuff and overspread the whole district. The tuff and calcareous shale have received the local name of 'Flat' formation. The massive lava-flow is called the 'Cliff' formation. It constitutes the escarpment just above the town.

Following the deposition of the Cliff lava, there was another lull in volcanic activity, during which 50 ft. of wind-stratified tuff was laid down. Then followed the most intense period of volcanic activity. Flow followed flow, until a mass of lava 2500 ft. thick had been piled upon the tuff beds. The various flows have been differentiated according to their physical characteristics and from bottom to top, have received the names of 'Tigre' 'Upper Tigre', 'Quartz-Rhyolite', 'Quartz-Mica Rhyolite', and 'Glassy Rhyolite'. The last constitutes the las



GEOLOGICAL SECTION OF

of the volcanic series and is found only on the mountain-tops.

Near the close of the volcanic era, the district was raised to approximately its present elevation, the sedimentary strata and lower volcanic flows being tilted to the south at an angle of 15°. The tilting, and possibly the uplift, were completed before the end of the volcanic period, for the upper flows are all thickest toward the south, thus equalizing the effect of the dip in the lower strata. At the close of the volcanic era, the region was probably fairly flat, with the surface at the height of the present mountain-peaks.

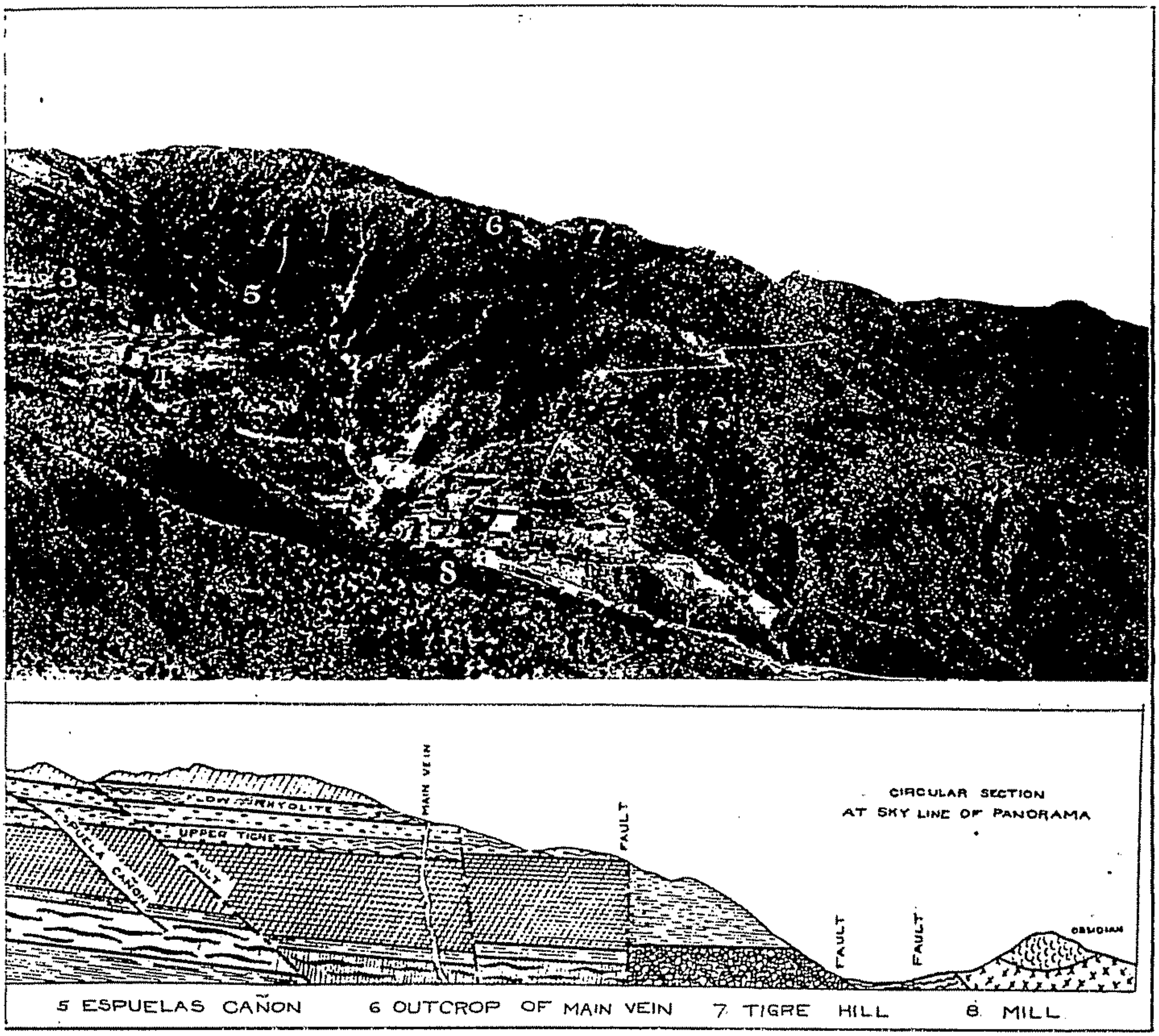
During the period of uplift the region about El Tigre was subjected to minor fracturing and faulting. Through the faults and fractures welled up metal-bearing solutions, which altered the rock of the lower members of the volcanic series and formed veins.

During and after the deposition of ore, the country was dislocated by extensive north-south faults and minor east-west faults. Andesite rose through the faults, forming dikes and stocks, and overflowing in places to form minor flows.

The general blocking out of the mountain ranges was effected by the north-south faults. Erosion followed and carved the mountains to their present shape.

DESCRIPTIVE GEOLOGY. The oldest sedimentary rock exposed in the district is limestone. From similarity in character and position to the Carboniferous limestone of Arizona, it has been classified as belonging to that period. It is fairly pure, of grayish blue color, and occurs in thick beds with a general dip of 30° west. Outcrops of limestone are found in the beds of Pita and Bota canyons, at Pilares de Teras and at the lime-kilns a mile west of El Tigre. Although the limestone does not outcrop within the Tigre quadrangle, its occurrence on three sides leads to the supposition that it underlies at least a part of the quadrangle.

Outcropping at the same general horizon as the lime-



THE EL TIGRE DISTRICT, IN SONORA, MEXICO

stone is an intrusion of granite consisting mainly of microline, sanidine, quartz, and phlogophite mica, the last now largely changed to serpentine and iron oxide. It is probably late Paleozoic. The granite is exposed in the canyons near the Tigre mill and also in Palomitas and Pita canyons. It probably underlies the greater part of the Tigre quadrangle.

The Nodular formation is the lowest member of the volcanic series. It was originally a glassy lava containing aggregates of spherules. The groundmass is now much kaolinized. The spherules are remarkably well developed, occasionally reaching a diameter of 18 inches. In places they are crowded so close together as to give the rock the appearance of a conglomerate. They are usually separated from the kaolinized groundmass by films of limonite or gypsum. Unaltered specimens contain 75% silica. The rock is classed as rhyolite.

Overlying the Nodular formation is a bed of rhyolite-tuff and calcareous shale; locallly this is termed the Flat formation. It is 500 ft. thick at El Tigre, but diminishes in thickness in all directions from the mining camp. The tuff is well stratified, indicating that it was deposited under water. The binding material is secondary calcite and quartz, the latter predominating. In many places the deposition of secondary silica has been so intense as to obscure the tufaceous character of the original rock, only slight tabular parting remaining along the original bedding-planes. Silicification is especially noticeable in the bottom of the formation and along old fissures and veins. Unchanged specimens of the tuff contain 71% silica, indicating that it should be classed as rhyolite.

The Cliff formation consists of a massive flow of fine-grained rhyolite, 250 ft. thick. It shows small phenocrysts of sanidine and quartz in a felsitic groundmass. The most important mine-workings are now in this formation. Near the vein-systems the formation is criss-crossed by minute quartz veinlets. The silicified rock is the hardest in the region and is being used with success in the tube-mills. The Cliff formation contains 80% silica and is classed as rhyolite.

Overlying the Cliff formation are beds of rhyolite-tuff, aggregating 60 ft. in thickness. It is always greatly altered, is the softest rock in the region, and is characterized by containing large cubes of secondary pyrite. Some of the best orebodiees have occurred in this formation. The tuff contains 71% silica, indicating that it should be classed as rhyolite.

The Tigre formation is a flow of rhyolite, 400 ft. thick, in which occurred the principal orebodies of the upper part of the mine. It is a medium-hard porphyritic rock with abundant crystals of sanidine and quartz in a felsitic groundmass. Pyrite, in small cubes, is abundant, especially near the veins. The Tigre formation contains 72% silica and is classed as rhyolite.

Overlying the Tigre formation are the Upper Tigre formation, quartz-rhyolite, quartz-mica rhyolite, and glassy rhyolite. All are porphyritic, containing crystals of sanidine, quartz, and mica in a glassy groundmass. The silica content ranges from 68% in the Upper Tigre formation to 81% in the quartz-rhyolite. No ore of commercial importance has been found in any of these flows.

Cutting through all the rocks of the region are a number of andesite stocks and dikes. One dike was intruded along the Sooy vein after ore deposition was complete. The North Tigre deposit occurs in a sill of this andesite. The wide distribution of andesite dikes along the whole Teras range and the occurrence of large bodies of andesite in the deeper canyons indicate that the andesite constitutes the core of the range. It seems possible likewise that the intrusion caused the faulting and general blocking out of the range, and may have been responsible for the ore deposition. The rock consists of minute laths of labradorite, interspersed with grains of augite. It contains 52% silica and is classed as augite-andesite.

Faults are numerous and in places produce dislocations of several hundred feet. All those observed are normal, that is, when the fault-plane is inclined, the upper side (or hanging wall) has slipped downward. All the major faults traverse the country in a general northwest-southeast direction, parallel to the axis of the range. Minor displacements cross the district in various directions.

The veins themselves are minor faults and represent the first fracturing in the region. While ore deposition was in progress, the south end of the main vein was intersected by a series of faults parallel to the vein, but dipping at a steeper angle westward. The total throw aggregates 200 ft. The best ore has been found near these faults. During the same period the north half of the vein was dislocated by three east-west faults, each with a throw of 50 ft. south. The principal deposits in the north half of the mine have occurred near these faults. In general the ore occurs in fractures and faults dipping west and is associated with fractures and faults dipping west and south. Faults dipping east or north were later than ore deposition and have no relation to it.

By far the greatest dislocations of the region have occurred during comparatively recent time. Two great fault-systems traverse the country in a northwest-southeast direction. The larger cuts diagonally across the south-west corner of the quadrangle, extending for miles along the foot of the high mountains. The entire western flank of the range has slid downward along this fault, the displacement ranging from 1500 to 3000 ft. This fault has been re-opened twice since 1880, both these re-openings being accompanied by severe earthquakes. The second largest fault traverses the centre of the quadrangle, passing between the mine and the mill. The east side has been dropped 500 ft. The two great faults have depressed both the central ridge and the western flank of the mountain range, leaving an intermediate zone stratigraphically higher than the formations on either side. The resulting inequality of the surface has been pared off by erosion till the zone is lower than the depressed areas. This explains why the oldest rocks of the region are found in the eroded area surrounding the mill, whereas the districts both east and west are composed of more recent lava-flows.

Three late faults cut the main vein. They all dip north. The throw is also to the north and ranges from 150 ft. for the two northernmost to 400 ft. for the most southerly. All three have dislocated the vein and have caused some confusion in the development of the mine. All are normal, and the recognition of this fact has aided materially in the solution of the fault problems.

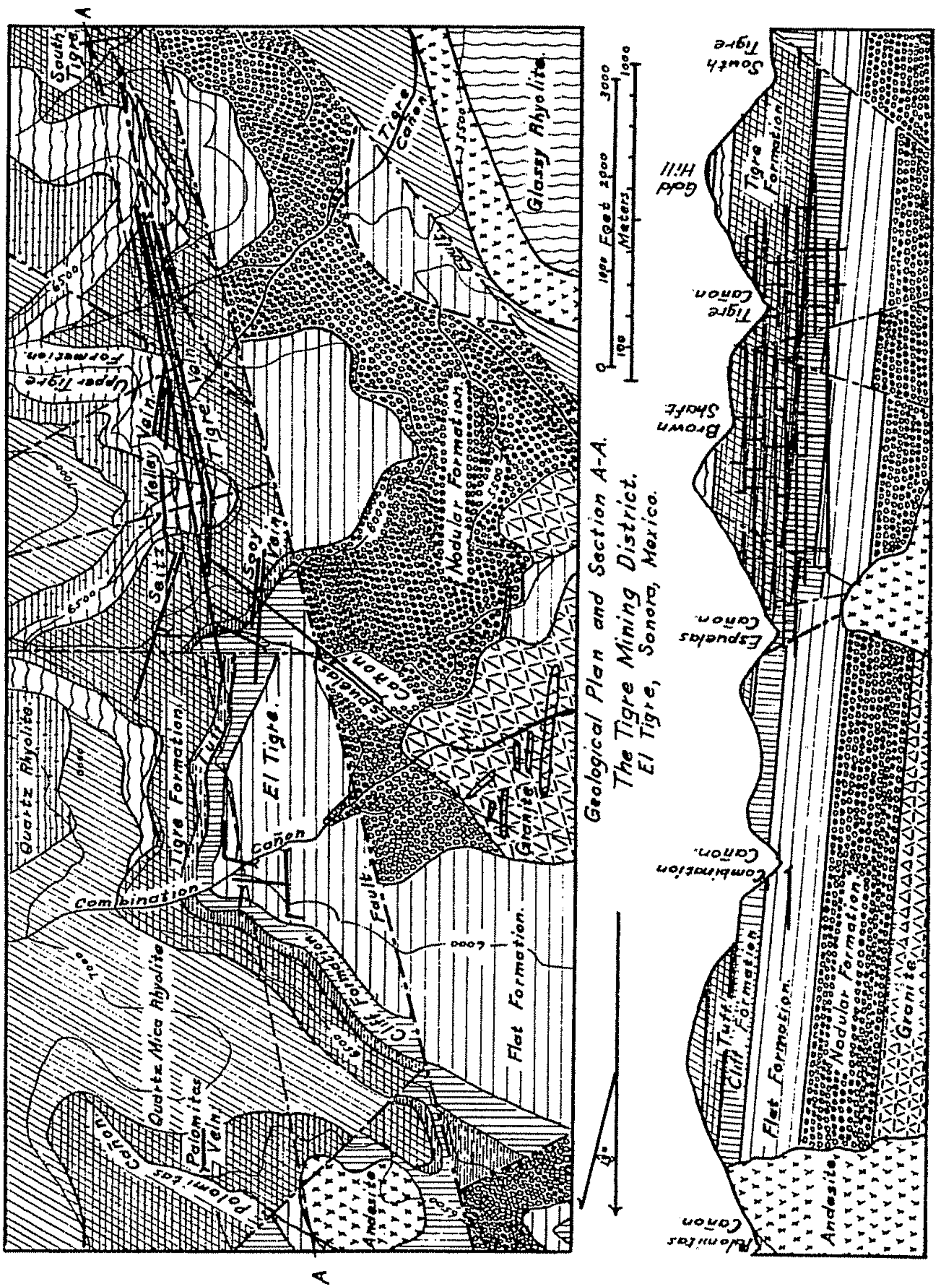
A simple rule for locating the continuation of faulted veins has been found to apply to normal faults: "If the fault dips from you as you face the end of the drift, cross-cut into the foot-wall of the vein; otherwise cross-cut into the hanging wall." The two words "from" and "foot-wall", beginning with 'f', aid in remembering the rule. The rule is not applicable to reverse faults and may not be applicable where there has been a side movement along the fault, or where the vein is nearly vertical and strikes nearly parallel to the fault; but it probably applies to 80% or more of the fault problems encountered in mining. It is suggested as a convenient rule of thumb for the practical miner.

Economic Geology. The Tigre mine is essentially a silver-gold property. Silver constitutes 85% of the value and gold 11%. Copper and lead are of secondary importance, each contributing about 2% of the total value.

Since the beginning of operations in 1903, the total ore extracted from the mine has amounted to 700,000 tons, assaying gold 0.25 oz.; silver, 39 oz.; copper, 0.25%; lead, 1%; and zinc, 1.5%. The various shipments to the smelters have aggregated 15,000 tons of shipping ore, 34,000 tons of concentrate, and 290 tons of bullion. The shipping ore and concentrate have averaged 2.7 oz. gold and 390 oz. silver per ton. The bullion has averaged 700 fine in silver and gold.

There are four important veins on the property of the Tigre Mining Company. Named from west to east, they are: the Sooy vein, the Tigre or main vein, the Palomitas-Protectora, and the Seitz-Kelley vein.

All the veins have been deposited along fissures. The filling is composed of kaolinized or party silicified country-rock, usually with deposition of quartz along the



Geological Plan and Section A-A.
The Tigre Mining District.
El Tigre, Sonora, Mexico.

fissure-planes and in the interstices between the fragments of country-rock. The ore consists of mixed sulphides of zinc, iron, lead, copper, and silver, with their decomposition products. Gold is associated with the copper. The ore occurs in discontinuous lenses of high-grade sulphides, and as low-grade impregnations in the vein-matter. The wall-rock is rhyolite and rhyolite-tuff; it is silicified at points where the veins are highly silicious, and kaolinized where silica is scant or lacking in the veins.

All the veins strike nearly north-south. The Tigre or main vein strikes N. 10° W. The Sooy, Palomitas-Protectora, and the Seitz-Kelley veins are parallel to each other, striking N. 5° E. The dip of all the veins is to the west, averaging 60°.

The Tigre, Sooy, and Seitz-Kelley veins are the only ones in the district that have been worked at a considerable profit. The Tigre has been the most productive, having yielded 90% of the ore so far produced. It extends from a point 300 ft. east of camp to the south slope of Gold Hill, a distance of a mile and a half.

The croppings are insignificant. Sulphide ore appears at one spot only, namely, in the south fork of Espuelas canyon, near the entrance to No. 2 level. Here the outcrop is 200 ft. long and six inches wide. A half-mile south, near the Brown shaft, a rich pocket of gold ore was found at surface. Again on Gold Hill, south of Tigre canyon, low-grade ore outcrops for a distace of 100 ft. Aside from these three insignificant showings, the croppings are scant and practically barren.

The development on the Tigre vein consists of ten levels, driven at 100-ft. intervals. Six only of these are adits.

The ore-channel so far developed on the Tigre vein is a mile long by approximately 700 ft. along the dip. It extends from Espuelas canyon on the north to the centre of Gold Hill on the south. The upper limit of the orebody coincides with Level A. The bottom limit roughly follows the contact between the Cliff and Flat formations, dipping south in conformity with the volcanic beds. Thus at the north end of the mine, the ore terminates on Level 5, while at the south end good ore continues below Level 8. Within the limits outlined two-thirds of the vein has been ore.

The average width of the vein is three feet. In places it narrows to a mere cleft, elsewhere it widens to 10 or 20 feet

The Sooy vein outcrops strongly in the Espuelas canyon, just south of camp, the sulphide ore coming to surface. It was at this outcrop that the first discovery was made. The vein is worked in conjunction with the Tigre. The orebody has the shape of an inverted equilateral triangle, 500 ft. on a side. The apex of the triangle rests on Level 8, the base on Level 3½. The ore occurs between the walls of the Tuff, Cliff, and Flat formations. The vein is much shattered, showing evidence of movement subsequent to ore deposition. The shattered condition has permitted surface-waters to come in contact with the sulphides, decomposing them. Much of the ore in the upper levels consists of oxides and carbonates.

Irregular dikes of andesite have intruded into the Sooy vein since its deposition.

The Seitz and Kelley deposits are on the same vein system. The Kelley deposit joins the Main vein just north of Tigre canyon. The junction of the two is poor The Kelley deposit is disc shaped, 500 ft. in diameter and three feet in average width. The deposits on the Seitz vein are 1000 ft. north of the Kelley deposit. They consist of small lenses, separated by extensive areas of barren vein-matter. The largest lens lies in the north end of the mine at the horizon of No. 2 level. It is elliptical, 600 by 100 ft., the longer axis being horizontal. The vein seldom exceeds six inches in width.

The Palomitas-Protectora vein extends from Combination hill to within a mile of the Bota canyon. From its position, dip, and strike it can be considered as the north extension of the Sooy vein. The deposit exposed in the Palomitas mine is roughly 150 by 50 by 3½ ft., and consists of oxidized ore assaying 0.11 oz. gold and 50 oz. silver per ton. The Protectora (North Tigre) deposit, as developed to date, is 1000 ft. long by 350 ft. deep by 2 ft. in average width. The ore consists of sulphides of zinc, lead, iron, and copper in a gangue of quartz and decomposed country-rock. The silver is associated with gray copper and chalcopyrite. Galena and sphalerite are the predominating sulphides. They assay much lower than at Tigre.

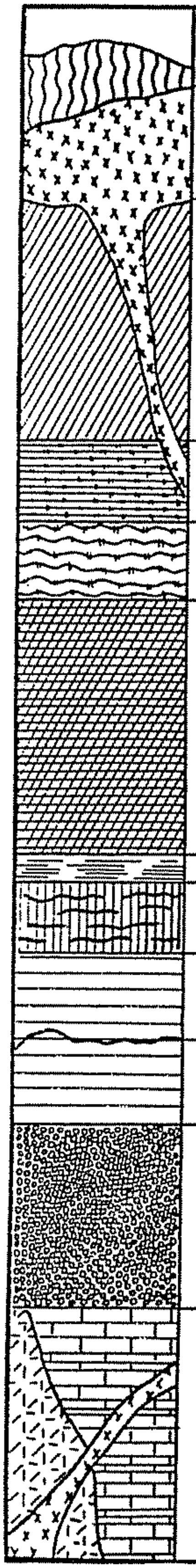
Relation of Ore Deposits to Stratification. Ore has been found at El Tigre only in the Tigre, Tuff, Cliff, and Flat formations. The deposit at North Tigre occurs in the Flat formation and in andesite. The character of the wall-rock has affected the shape of the ore deposits. In the Tigre formation, the veins are of fairly uniform width, varying from one to five feet, and increasing to greater width only near the intersections with cross-veins. The deposits are continuous for long distances. Branch veins, with the exception of the Kelley vein, are short in extent.

In the Tuff formation the vein is extremely variable in width. In most places it consists only of a talc seam with no ore. At cross-fractures or branch veins the width is sometimes 20 ft. In all cases the deposits are irregular and difficult to follow.

In the Cliff formation the brittle character of the rock has been especially favorable for fracturing. The ore characteristically occurs in two or more veins. Usually both the veins and the walls are hard and firm.

Ore has been found in the Flat formation only in the Sooy vein. Here the deposit was lenticular, 200 ft. in diameter and 20 ft. in maximum thickness. The ore consisted of sulphides of copper, zinc, and lead, in a quartz gangue. The silver was associated with the copper minerals (as is the case at North Tigre) and not with the zinc and lead, as in other Tigre deposits. It is possible that the lower Sooy orebody was deposited at the same time as the North Tigre ore.

There appears to be little relation between wall-rock and the character of the ore. This is especially true as regards the silver and lead minerals. There is perhaps a slightly increased proportion of chalcopyrite and gold



OBSIDIAN.	ACID GLASS, MOST RECENT FLOW IN THE DISTRICT.
ANDESITE	AUGITE ANDESITE, CUTTING ALL OF THE UNDERLYING FORMATIONS.
QUARTZ MICA RHYOLITE 400'-700'	HOMOGENIOUS MASS, SHOWING ABUNDANT PHENOCRYSTS OF QUARTZ AND BIOTITE.
QUARTZ RHYOLITE 150'-300'.	DEVITRIFIED RHYOLITE, MICROCRYSTALLINE GROUND MASS, PROMINENT PHENOCRYSTS OF QUARTZ.
UPPER TIGRE FORMATION. 200'-300'.	SODIC RHYOLITE, CHARACTERIZED BY TABULAR WEATHERING AND A TENDENCY TO FORM CLIFFS.
TIGRE FORMATION 350'-700'.	DEVITRIFIED RHYOLITE, CHARACTERIZED BY ABUNDANCE OF ALKALINE FELDSPARS.
TUFF 60'-100'	RHYOLITE TUFF.
CLIFF FORMATION 250'	FINE GRAINED RHYOLITE, CHARACTERIZED BY TENDENCY TO FORM BOLD CLIFFS.
FLAT FORMATION 200'-300'.	RHYOLITE TUFF WITH OCCASIONAL BEDS OF LIMESTONE AND ARGILLACEOUS SEDIMENTS DISTINCTLY STRATIFIED.
SILICIFIED FLAT FORMATION. 200'-300'	SHOWS INTENSE SILICIFICATION AND TABULAR PARTING PARALLEL TO FORMER BEDDING PLANES.
NODULAR FORMATION, 500'-700'.	FORMERLY GLASSY RHYOLITE, CHARACTERIZED BY AGGREGATES OF SPHERULES.
GRANITE AND LIMESTONE CUT BY ANDESITE DYKES.	COARSE GRAINED MICA GRANITE. COMPARATIVELY PURE LIMESTONE OCCURRING IN THICK BEDS.

COLUMNAR SECTION OF LOCAL GEOLOGY

in the Cliff and Flat formations. Zinc-blende also is more noticeable in the bottom of the mine, but this may be due to its susceptibility to the agencies of secondary enrichment.

GENESIS OF ORE DEPOSITS. There are two possible explanations of the genesis of the ore deposits.

The first is that the ore deposition was associated with deep-seated granitic intrusions from which the rhyolite flows were derived. Such intrusions have been clearly recognized in the Chitahueca mountain 25 miles to the east. It is possible also that the granite of Pita canyon was of this age, for it is much fresher than the Pre-Tertiary granite at the Tigre mill. The possibility of an extensive intrusion of Tertiary granite beneath El Tigre is indicated by the tilting of the lower volcanics before the extrusion of rhyolite was complete. The tilting of the volcanics could have caused the minor fracturing and faulting associated with the vein formation. The vein-filling could have been dissolved from the cooling intrusion and contiguous rocks. The granitic intrusion unquestionably contained silver, for the rhyolites, derived from it, average 0.1 oz. silver per ton.

The second theory is that the ore deposition was associated with the great post-volcanic intrusion of andesite which underlies the region. The presence of extensive dikes and stocks of andesite near all the large ore deposits is a strong argument in favor of this theory. The occurrence of the North Tigre deposit in andesite proves that ore deposition followed at least the first manifestation of the andesitic intrusion. On the other hand, andesite dikes which traverse the Sooy vein prove that ore deposition preceded at least the last manifestation of the andesitic intrusion. Conceivably the dikes cutting the Sooy vein were derived from the molten core of the main intrusion, after the cooling exterior had caused the formation of the orebodies. The Sooy and North Tigre ores are sufficiently similar to each other and to the ores of the other veins to indicate the same source for all the ores of the region. It can therefore be argued consistently that the ores of the Tigre district were deposited while the andesite intrusion was solidifying and cooling. Thus the andesitic intrusion fills the modern requirement of a cooling igneous intrusion (preferably basic) as the source of the ore-bearing solutions.

The andesite assays 0.06 oz. silver per ton, and the rhyolite, lying between the andesite and the ore deposits, assays 0.10 oz. per ton. The ground-water at Tigre is noticeably charged with alkaline sulphides.

It is not unreasonable to suppose that the veins were formed by hot alkaline-sulphide solutions, which derived their heat and part of their mineral content from the cooling intrusion. Part of the minerals may have been derived from the rhyolite and other rocks overlying the andesite intrusion.

In connection with the above theory it is interesting to note that the volcanic rock beneath the ore deposits have been greatly altered for a distance of 100 yards or more on each side of the veins. The alterations in the Nodular formation take the form of kaolinization and loss of silica in the groundmass. The Flat formation is intensely silicified. In the Cliff, Tuff, and Tigre formations there is extensive deposition of secondary pyrite. The altered rocks assay less in silver than unaltered specimens of the same rock. A possible explanation is that the ascending mineral-bearing solutions were partly confined beneath the shale in the bottom of the Flat formation, and spread laterally through the Nodular formation, following the lines of weakness between nodules and groundmass. The groundmass has been much leached, analysis showing a marked reduction in silica, iron, and silver. After the solution had finally forced diffusion through the shale of the Flat formation, the pressure was reduced sufficiently to permit the deposition of silica, which is so marked in this formation. On diffusing still higher into the Cliff, Tuff, and Tigre formations, the solutions dissolved more metals. Iron, being the predominating metal in the rocks, saturated the solutions and was precipitated as pyrite in the rock itself. The other metallic sulphides, together with the remaining iron and silica, entered the veins in a manner analogous to lateral secretion, being precipitated on encountering the reduced pressure and temperature of the open fissures.

The above theory is suggested because it appears to explain the relation existing between the veins and the pyritization and silicification of the wall-rock. This relation has been so repeatedly verified by development work that it has come to be an axiom that the ore is to be sought at the horizon where pyrite occurs in the wall-rock, and just above the horizon of intense silicification.

SECONDARY ENRICHMENT. Secondary enrichment has only slightly affected the orebodies. Most of the ore is primary. This is especially true in the north end of the mine, where the sulphide grains are completely encased in quartzose vein-matter. Here sulphide ore outcrops and shows little evidence of leaching or enrichment.

Farther south the vein is less silicious, and hence more pervious to water. The upper part of the deposit has been leached to a depth of 200 ft. or more. In the leached zone silver ore usually occurs as chloride; only occasionally as sulphide, where the denser portions of the vein lent some protection to the sulphide grains. In the early days of the district a rich gold deposit was found just south of the Brown shaft. The deposit consisted of native gold in an iron-clay gangue. Little silver was present. On the strength of this discovery the company was called the Lucky Tiger Combination Gold Mining Company. Development in depth has shown the silver to be ten times as valuable as the gold. Only the name of the company remains to show that the discoverers thought they had found a gold mine. Undoubtedly, the original silver minerals of the Brown shaft deposit had been removed by the leaching action of surface-waters.

Beneath the leached zone is an ill-defined zone of secondary enrichment. Veinlets of stromeyerite traverse the wall-rock and the original silicious-sulphide ore. In one case a seam of native silver, a quarter inch in thickness, was observed traversing low-grade galena.

MINERALOGY. The Tigre ore consists of metallic sulphides (or their decomposition products) in a gangue of quartz and decomposed or silicified rhyolite. Named in order of their preponderance the sulphide minerals are: sphalerite, galena, pyrite, chalcopyrite, stromeyerite, and freibergite. The sulphides are invariably much intergrown. Crystals, apparently pure, show traces of other metals on analysis. The rich ore of the Tigre mine is freibergite or stromeyerite containing lead and iron as impurities. The finely crystallized sphalerite and galena are usually intergrown with minute particles of stromeyerite. Hence such ore is generally high in silver. When coarsely crystalline, sphalerite and galena are much lower in silver. Sphalerite generally assays higher than galena. Pyrite is practically barren of silver.

In the oxidized portions of the veins, the important minerals are native gold, native silver, and cerargyrite (hornsilver). A unique occurrence of gold was found in the upper part of Gold hill; it consisted of a druse of fine gold deposited upon a crystal of hornsilver.

Gold is usually associated with chalcopyrite. There is no fixed ratio between gold and silver. One of the samples richest in gold (900 oz. per ton) contained only 100 oz. of silver. Likewise the high-grade stromeyerite ore is practically barren of gold. Only by averaging the production over long periods can any definite relation be found between the gold and silver. For each ounce of gold produced since the inception of operations, the mine has yielded 162 ounces of silver.

CONCLUSION. The knowledge gained by geologic study has proved of much value in the development of the mine. The study of the stratigraphy of the lava-flows has helped in the solution of fault problems and has served to indicate the horizons at which ore may be encountered. The knowledge of the characteristics of the veins in the various volcanics has made possible more intelligent systems of development and mining. The relation between ore deposits and faults dipping south and west has been another aid in the discovery of ore. Likewise the relation between ore deposits and pyrite in the wall-rock has helped in the search for new orebodies—especially by diamond-drilling. Finally, the fact that the zone of ore deposition lies immediately above the zone of intense silicification, has aided in following the trend of the orebodies and in avoiding unprofitable development work.

In conclusion I wish to acknowledge the participation of C. M. Heron in the preparation of this article. He did much of the field-work and prepared the original maps and sections. The petrographic work was done by Professors George D. Louderback and G. H. Cox. I desire especially to thank L. R. Budrow, general manager for The Lucky Tiger Combination Gold Mining Company for authorization of the work and for constant suggestions and criticisms throughout its progress.