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RECONNAISSANCE GEOLOGY OF ISLA MEJIA, GULF OF CALIFORNIA, MEXICO[1]

PART I - GEOLOGY

By

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INTRODUCTION

A reconnaissance geologic and magnetic survey was made of Isla Mejia, Mexico, during the last two days of December, 1969. Isla Mejia is located in the Sea of Cortez at the north end of Angel de la Guarda (Figure 1) where it forms the northern portion of the excellent harbor known as Puerto Refugio. The U. S. S. Narragansett survey of 1873-1875 established a monument on the south end of the island, which was surveyed to be 29° 33' 07.8" N. latitude and 113° 35' 19.2" W. longitude (U. S. Department of the Navy). The island has a maximum length of approximately 1½ miles in a northerly direction (Figure 2), and is about 1 mile wide in an east-west direction. The highest point of the island is 857 feet above sea level. The vegetation is typical Sonoran Desert type. The island has been described as "Dantes Inverno" (Cannon, 1966) because of the brightly colored craggy rocks present in the precipitous sea cliffs; however, the bold colors of the rock formation coupled with the clear blue water surrounding the island form a locale of unusual beauty combining the best of both the desert and the sea. No evidence of fresh water was found on the island and the animal life observed was restricted to lizards, bats, insects, and birds. Marine life in the waters surrounding the island are very abundant with the local strong tidal currents bringing in food for the many varieties of sea life (Steinbeck, 1962). The closest permanent settlement is Bahia de los Angeles, located on the east coast of Baja, California, 48 miles south of Isla Mejia.

Approximately two-thirds of the island was examined on foot during this survey and colored aerial photographs were used to complete the study of the geology of the remainder of the island. Outcrop exposure is excellent with approximately 70 percent of the bedrock exposed. A magnetic survey was conducted by Marsh. His results and interpretations are described in an accompanying paper (Part II).

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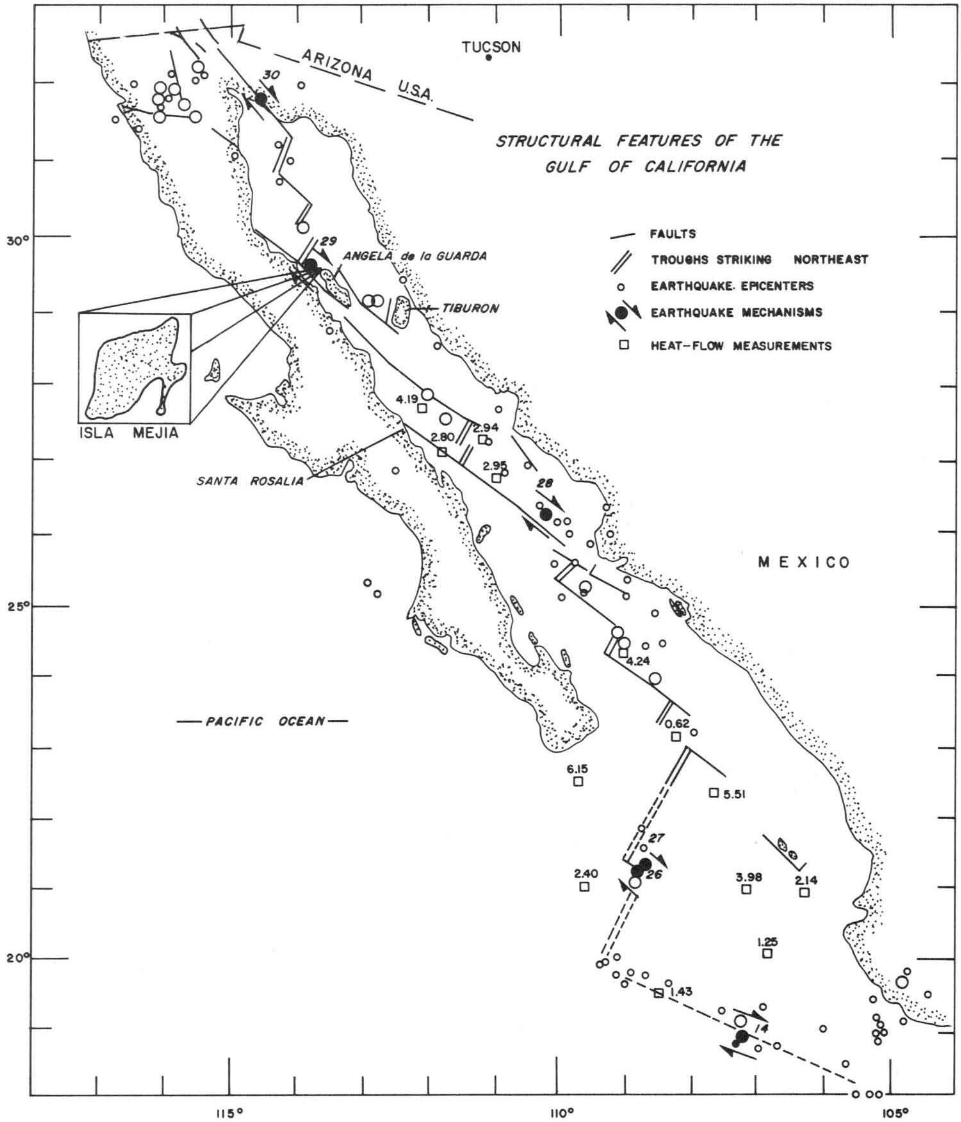

Figure 1.--Seismicity, Heat-flow of the Gulf of California and the Regional Location of Isla Mejia; the Seismicity and Mechanism Numbering (whole numbers) after Sykes (1968); Heat Flow Valves After Von Herzen (1963).

ROCK TYPES

The oldest rocks which are located peripherally around the entire island consist of a sequence of thin-bedded alternating sands and finer clastic material which has been metamorphosed to banded quartzite. The beds, which range in thickness from 1 to 4 inches, consist of blue-grey quartzite interbedded with dark grey siliceous material. Locally, deformation and shearing of the rocks is accompanied by development of sericite and chlorite. Zones of stretching, elongation, flowage, small-scale folds and boundinage-like structure locally have formed by deformation of the thin beds. The deformed nature of the rock is attributed to post-depositional soft sediment submarine slumping and movement. The formation becomes a massive quartzite at the southwestern portion of the island. This may be the result of the primary deposition, or post-depositional underwater slumping may have locally homogenized the units. In thin section the rock consists of subrounded fine- to medium-grained compacted quartz with very minor clay and iron oxide development. This formation is inferred to represent a former clastic marine sequence which was formed at the distal end of turbid flows and subsequently, has been dynamically and thermally metamorphosed by volcanic and intrusive activity.

The quartzite sequence has been intruded along a north-south axis near the center of the island by a complex quartz diorite-granodiorite igneous body. The medium- to coarse-grained hypidimorphic rock consists of quartz (10 percent), plagioclase (An$_{58}$, 55) percent), myrmekite and orthoclase (10 percent), biotite, (10 percent), hornblende (15 percent), with traces of apatite, rutile, zircon, sphene, sericite, and opaque minerals. The plagioclase shows normal and oscillatory zoning. Rutile exsolution laminae are evident in the biotite. Pyrite with traces of chalcopyrite was observed in a more acid facies of the intrusive at the north end of the island. The intrusive rocks of the granitic complex crosscut the metamorphic rocks. Dikes of granodiorite and felsite were observed intruding the quartzite and a baking effect was noted along the contact zone. Similar appearing intrusive granitic rocks from nearby Baja, California, have been dated as late Cretaceous (McFall, 1968).

A long period of erosion followed with the development of a major unconformity. This time interval was terminated by deposition of at least a few hundred feet of flat lying red arkosic sandstone which forms the highest portion of Isla Mejia. This medium- to coarse-grained, subround, spherical iron stained sandstone consists of predominately quartz with chert, potash feldspar and a few lithic fragments of volcanic rocks. The grains are cemented by carbonates forming a moderately indurated rock. The quartz and feldspars were probably derived from erosion of the basement metamorphic rocks and the Baja Peninsula granodiorite batholith; the lithic volcanic material was formed as a result of major volcanic activity which occurred in this area during the middle Tertiary. Long cross beds are present in the formation. The lowermost sandstone beds contain numerous pebble to cobble sized fragments of the underlying granodiorite and quartzite. The uppermost beds of this formation, which form the highest point on the island, become more quartzose and less arkosic.

Volcanic dikes were observed crosscutting the sandstone. The effect of baking of the sandstone along the dike contacts was quite pronounced with the development of a few inches of resistant rock at the contact.

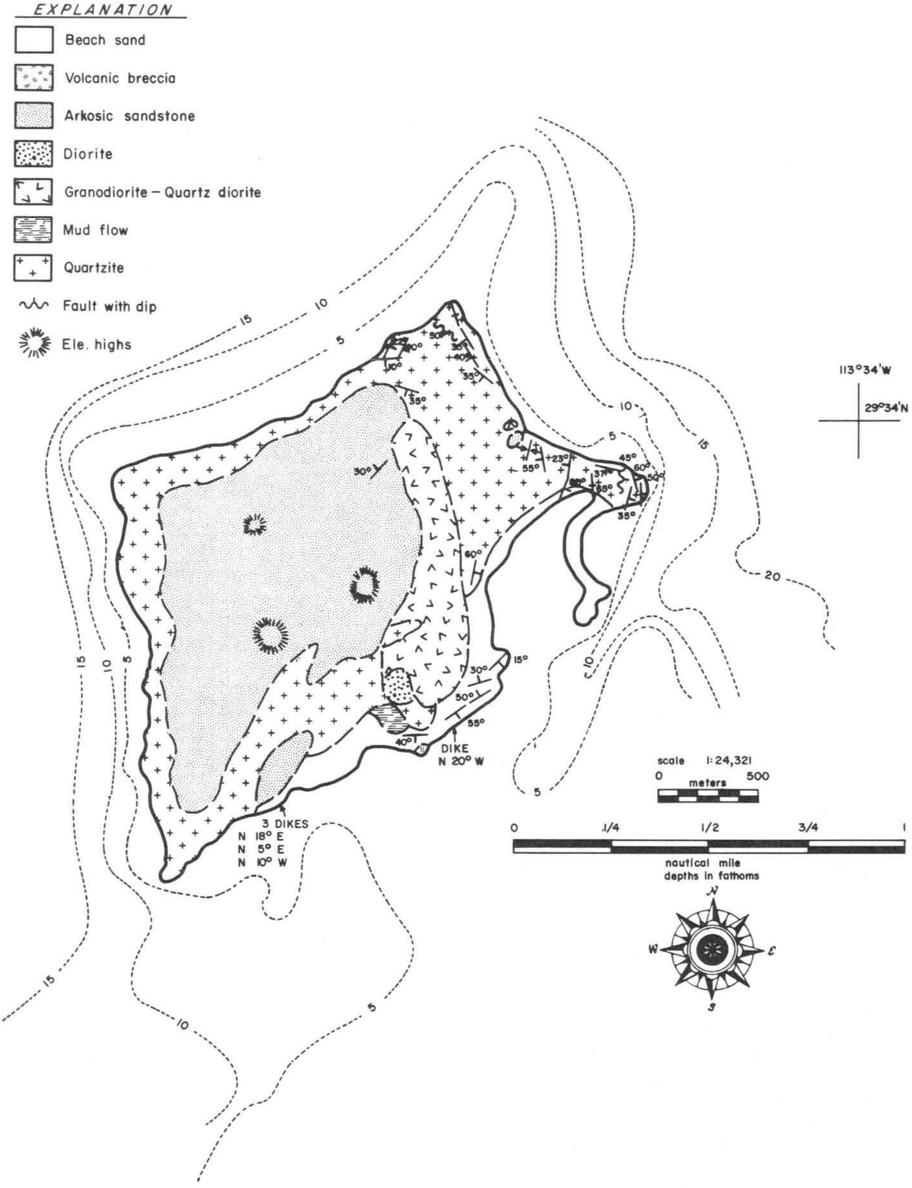

Figure 2.--Reconnaissance Geologic Map of Mejia Island, Gulf of California.

The youngest rock on Isla Mejia is an explosive volcanic breccia which is found in one small outcrop a few hundred square feet in area on the south side of the island at the water's edge. The breccia consists of fragments of basalt, quartzite, tuff, and granodiorite. A few fragments show slight rounding which is attributed to either surface erosion or corrasion during volcanic activity. The latter is favored because thin sections indicate that the matrix material locally has a volcanic trachytic texture. Late carbonate veinlets crosscut the rock.

Some vitrophyre float was observed on the higher ground at the southeast corner of the island. The occurrence and geologic relations of this rock type were not mapped during this study.

Unconsolidated alluvium is very sparse on the island except for beach sand. A large boulder-filled mudflow is present in a canyon in the south central portion of the island. This mudflow is about 10 feet high and 100 feet wide and can be traced for hundreds of feet up canyon.

STRUCTURE

Two normal faults of undetermined magnitude crosscut the metamorphosed basement rocks. Other faults can be inferred in the igneous complex where the more rugged topography appears to be fault controlled. A N. 30° E. trending shear zone tens of feet wide and hundreds of feet long is located on the south side of the island near the inlet close to the beach. This northeasterly direction is normal to most of the major structures observed and recorded in the Sea of Cortez area (Figure 1). The perimeter of the island on the north and east coasts appears to be structurally controlled by fault zones with local modification caused by the strike of the resistant quartzite formation. The general trend of the coastline and the strike of quartzite beds are approximately parallel. It is apparent that the basement rocks are very resistant to marine erosion and the island is not eroded more rapidly because of the durable metamorphic and igneous complex. The smaller surrounding islands such as Sail Rock and Granite Island and the various reefs appear to consist wholly of the resistant basement rocks.

Folds of moderate amplitude are present in the quartzite, especially along the northeastern beaches (Figure 2). No folds were observed in the younger arkosic sandstones, but this formation has been tilted to the northwest.

REGIONAL STRATIGRAPHY

The following regional geologic observations which are based upon the limited geologic literature of the region, are presented to show the similarities of geologic features between Isla Mejia and the surrounding islands and the adjoining mainland. The most detailed geologic study pertinent to the central Sea of Cortez is a reconnaissance study of Concepcion Bay (McFall, 1968), which is located in Baja, California, about 200 miles to the southeast. The basement complex in the Concepcion Bay area consists of a granodiorite-quartz monzonite batholith containing schists, which are in places gradational to the granitic rocks. The age of the batholith is 78.4± 2.9 my (McFall, 1968). Overlying this complex unconformably is the Commondu group of which the basal member consists of over a thousand feet of red cross-bedded tuffaceous sandstone called the Salto formation. Fragments of the underlying granites and schists are found above the unconformity in the basal sandstone beds. The lithologic description of the Salto formation is similar to that observed in the younger red sandstone of Isla Mejia. The date of the Salto formation was established as late Oligocene (28.1± 0.9 my).

In the Santa Rosalia area (Boleo Copper district), Baja, California, (Figure 1), Touwaide (1930) described a pink, very hard, highly recrystallized quartzite as intruded and metamorphosed by the Baja batholith. Wilson (1948), however, described this quartzite as the lowermost Commondu which he states is depositionally resting upon the plutonic rock rather than intruded by the batholith.

Other occurrences of basement quartzite are reported (Anderson, 1950) from Tiburon Island, 80 miles to the east-southeast, and also at the south end of Angel de la Guarda, 40 miles south of Isla Mejia. On Tiburon Island the oldest rock observed consisted of hornfels, quartzite, schist and marble, which were, in turn, intruded by quartz diorite. This basal sequence is overlain by a series of red beds and arkoses which are cross-bedded and include pebbles of the underlying quartz diorite. Anderson reports that parts of Angel de la Guarda are formed on a basement complex of metamorphic and granitic rocks overlain by volcanic rocks which include reddish siltstones near the base.

The California Academy of Sciences (Lindsay, 1966) reports metamorphic rocks in the quartz diorite at the north end of Tiburon Island. Slates and banded quartzites were found on Isla Turner just south of Tiburon Island. Lindsay further describes thinly laminated quartzite as a common occurrence in the mid-Gulf island basement rocks. The senior author (P. H.) has observed metamorphosed shales and sandstones within the granitic rocks immediately north of Puerto Libertad, Sonora, on the mainland coast.

A short aerial reconnaissance of Angel de la Guarda conducted in January, 1970, indicated that the 40-mile long island consists almost wholly of Commondu(?) volcanic rocks unconformably overlying a granitic basement. A possible caldera was observed south of the mid island low area approximately 30 miles south of Isla Mejia.

REGIONAL STRUCTURE

The Gulf of California is generally believed to have formed from the rafting of the Baja, California, peninsula from the mainland of Mexico. It is one of two places on the earth where an oceanic spreading center--the East Pacific Rise--intersects a continental land mass. The unraveling of the evolution of this particular relationship is of paramount importance if we are to wholly understand global tectonics.

Some students (Atwater, 1970; Chase, et. al., 1970) feel that the East Pacific Rise is transformed from the mouth of the Gulf by way of a number of en-echelon faults throughout the Gulf to the San Andreas system where this system then completes the transform to the Gorda and Juan de Fucca ridges. Others contend that the East Pacific Rise has been overriden by the North

American plate and that the ridge is now operating beneath the western United States (Heezen, 1960; Cook, 1962, 1966). It is beyond the scope of this paper to fully debate this problem, but it now appears (Chase, et. al., 1970; Atwater, 1970) that the former hypothesis is correct. Aside from this problem, the existence and exact nature of the East Pacific Rise within the Gulf itself remains as an unknown.

Geophysical data within the Gulf certainly reflect the active tectonics taking place there today. Geothermal heat flow measurements (Von Herzen, 1963) in and around the Gulf of California (Figure 1) show an average value of 3.12×10^{-6} cal/cm^2/sec, compared to the average oceanic and continental geothermal heat flow of 1.50×10^{-6} cal/cm^2/sec. These heat flow data are even higher than the average value observed for oceanic ridges which is about 1.80×10^{-6} cal/cm^2/sec (Stacey, 1969, p. 240). Seismic refraction studies in the Gulf (Phillips, 1964) show an average depth to the upper mantle of 8.9 km, with an average velocity (Pn) of 7.7 km/sec as compared to a "normal" world Pn velocity of 8.1 to 8.2 km/sec. This low upper mantle velocity is characteristic of most regions exhibiting high heat flow, as, for example, the Basin and Range Province where high heat flow is observed (Warren, et. al., 1969) along with Pn velocities of 7.8 to 7.9 km/sec. Bouguer gravity data (Harrison and Mathur, 1964) show a large positive anomaly which quite closely follows the deepest part of the Gulf from south to north. This anomaly ranges from about -100 mgls in the southern portion to about 20 mgls in the northern most portion of the Gulf (above latitude 28°N). This anomaly has been interpreted by Harrison and Mathur as a dense nearly vertical block of oceanic type crust which is flanked by continental type crust on either side. Sykes (1968) has interpreted the earthquake mechanisms in the Gulf (see Figure 1) as strongly suggesting the presence of a ridge within the Gulf, and that the epicenter locations and movement patterns are similar to those of mid-oceanic ridges (Sykes, 1969). To our knowledge no definitive magnetic data exist pertaining to the Gulf of California proper although this would be an excellent geophysical method to employ to seek the whereabouts and nature of the ridge if it does indeed exist here.

The Gulf probably began forming in early or middle Miocene (Rusnak and Fisher, 1964), and by the end of the Miocene the northern and central portions of the Gulf had moved enough to form a narrow proto-Gulf. Shortly after this time the Angel de la Guarda-San Esteban slice was formed (Figure 1), where Isla Mejia also lies. Bathymetric data indicate a strong fault is located along the west side of Angel de la Guarda island and Isla Mejia. The southern portion of the Gulf seems to have sluggishly followed the movements of the two northern sections except that because of differences in the thickness of pelagics on the east and west flanks of the ridge in the mouth area, a period of quiesence lasting at least 6 million years seems to have prevailed before the present cycle of spreading began (Moore and Buffington, 1968) in this region of the Gulf.

The island of Angel de la Guarda and consequently Isla Mejia and neighboring waters, because of their critical position on a slice of continental crust somewhat straddling the Gulf, could offer directly observable evidence as to the presence of a ridge or active global tectonics. It was under this motivation that this study was launched.

REFERENCES

Anderson, C. A., and others, 1950, Geology of Islands and Neighboring Land Areas, 1940, E. W. Scripps Cruise to the Gulf of California: Geol. Soc. America, mem. 43, p. 1-53.

Atwater, Tanya, 1970, Implications of Plate Tectonics for the Cenozoic Tectonic Evolution of Western North America: Geol. Soc. America Bull., v. 81, p. 3513-3536.

Beal, C. H., 1949, Reconnaissance of the Geology and Oil Possibilities of Baja, California, Mexico: Geol. Soc. America, mem. 31, 131 p.

Cannon, Ray, 1966, The Sea of Cortez: Lane Magazine and Book Co., Menlo Park, California, 284 p.

Chase, C. G., H. W. Menard, R. L. Larson, G. F. Sharman III, and S. M. Smith, 1970, History of Sea-Floor Spreading West of Baja, California: Geol. Soc. America Bull., v. 81, p. 491-498.

Cook, K. L., 1962, The Problem of the Mantle-Crust Mix: Lateral Inhomogeneity in the Uppermost Part of the Earth's Mantle: Lansberg, H. E. (ed.), Advances in Geophysics, Academic Press, New York, v. 9, p. 295-360.

________, 1966, Rift System in the Basin and Range Province in the World Rift System: Geol. Survey of Canada Paper 66-14, p. 246-279.

Hamilton, Warren, 1961, Origin of the Gulf of California: Geol. Soc. America Bull., v. 72, p. 1307-1318.

Harrison and Mathur, 1964, Gravity Anomalies in the Gulf of California: T. H. vanAndel, and G. G. Shor (eds.), A. A. P. G., Marine Geology of the Gulf of California, mem. 3, p. 76-89.

Heezen, B. C., 1960, The Rift in the Ocean Floor: Scientific American, v. 203, Oct., p. 98-110.

Lindsay, George E., 1966, The Gulf Islands Expedition of 1966: Proceedings of the California Academy of Sciences, 4th Series, v. 30, no. 16, p. 309-355.

McFall, C. Carew, 1968, Reconnaissance Geology of the Concepcion Bay Area, Baja, California, Mexico: Stanford University, Stanford, California, 25 p.

Moore, David G., and Edwin G. Buffington, 1968, Transform Faulting and Growth of the Gulf of California Since the Late Pliocene: Science, v. 161, p. 1238-1241.

Nelson, Edward W., 1922, Lower California and its Natural Resources: National Academy of Sciences, v. 16, mem. 1, p. 1-194.

Phillips, R. P., 1964, Seismic Refraction Studies in the Gulf of California; T. H. vanAndel, and G. G. Shor (eds.), A.A.P.G., Marine Geology of the Gulf of California, mem. 3, p. 90-121.

Rusnak, G. A., R. L. Fisher, and R. P. Shepard, 1964, Bathymetry and Faults of Gulf of California: T. H. vanAndel and G. G. Shor (eds.), A.A.P.G., Marine Geology of the Gulf of California, mem. 3, 408 p.

_______, and R. L. Fisher, 1964, Structural Evolution of Gulf of California: T. H. vanAndel and G. G. Shor (eds.), A.A.P.G., Marine Geology of the Gulf of California, mem. 3, p. 144-156.

Stacey, Frank D., 1969, Physics of the Earth: John Wiley and Sons, Inc., New York, 324 p.

Steinbeck, John, 1962, Log From the Sea of Cortez: Viking Press, Inc., New York, 282 p.

Sykes, L. R., 1968, Seismological Evidence for Transform Faults, Sea-Floor Spreading, and Continental Drift: R. A. Phinney (ed.), The History of the Earth's Crust, Princeton Univ. Press, p. 120-150.

_______, 1969, Seismicity of the Mid-Oceanic Ridge System: H. L. Pembroke (ed.), The Earth's Crust and Upper Mantle, Geophysical Monograph no. 13, American Geophysical Union, 735 p.

Touwaide, M. E., 1930, Origin of the Boleo Copper Deposit, Lower California, Mexico: Econ. Geol. v. 25, p. 113-144.

U. S. Dept. of the Navy, Hydrographic Office, 1966, Anchorages in the Gulf of California, Region 2, Map 638: USS Narragansett Survey 1873-1875.

Von Herzen, Richard P., 1963, Geothermal Heat Flow in the Gulf of California and Aden: Science, v. 140, no. 3572, p. 1207-1208.

Warren, R. E., J. G. Schlater, V. Vacquier, and R. F. Roy, 1969, A Comparison of Terrestial Heat Flow and Transient Geomagnetic Fluctuations in the Southwestern United States: Geophysics, v. 34, no. 3, p. 463-478.

Wilson, Ivan F., 1948, Buried Topography, Initial Structures, and Sedimentation in Santa Rosalia Area, Baja, California, Mexico: Am. Assoc. Petroleum Geologists Bull., v. 32, no. 9, p. 1762-1807.

_______, and V. S. Rocha, 1955, Geology and Mineral Deposits of the Boleo Copper District, Baja, California, Mexico: U. S. Geol. Survey Prof. Paper 273, 134 p.