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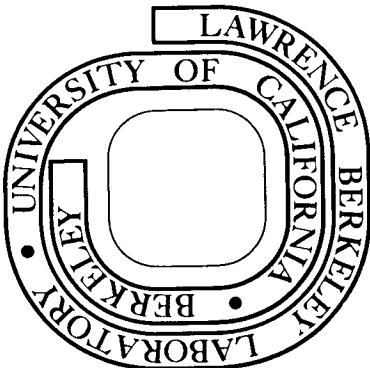
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GEOLOGY AND GEOTHERMAL RESOURCES OF THE SALTON  
TROUGH, CALIFORNIA IN RELATION TO RIFT ZONE TECTONICS

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The 225 km long by 60 km wide Salton Trough of southeastern California and the adjacent area of the Cerro Prieto geothermal field in Mexico exhibit zones of step-faulting with 1 km or more of cumulative vertical offset, high heat flow, earthquake activity, young volcanics, and tensional basins that suggest major components of rift tectonics. Drilling and geophysical exploration of six geothermal energy fields has yielded data that elaborate on the earlier idea of "pull-apart-basins" between en echelon transform faults. Observations along the transform-rift junctions in the FAMOUS area of the Mid-Atlantic Ridge provide a useful tectonic model. Specifically, Transform-A is 20 km long with an 8 km wide valley that contains an axial zone 3 km in width and a vertical relief of 600 m. Slopes of the axial zone are  $30^{\circ}$  to  $45^{\circ}$  and show normal faulting of greater than  $60^{\circ}$ . There is also a topographic depression at the intersection of Transform-A and the rift axis, pillow lavas, hydrothermal activity, and dike swarms. These details and scales fit models for the Salton Trough geothermal area. Ongoing submersible research at the Tamayo Fracture Zone-East Pacific Rise Junction south of Baja California appears to offer a complimentary analogy. Slivers of the five major strike slip faults in the Salton Trough--the San Jacinto, Elsinore, San Andreas, Imperial and Cerro Prieto-- separate wedge-shaped blocks and may be characterized as

"leaky transforms" that aid in explaining observed geothermal anomalies. Earthquake hypocenters range from 0 to 15 km with clusters at 2 and 5 km in a 20 km thick crust. A sedimentary rock section 4 to 6.5 km in thickness fills the trough and was derived from the ancestral Colorado River delta, yet also consists of shallow marine, lake, and coal units that together have almost kept pace with subsidence. Hydrothermal metamorphism is occurring at depths of 1 to 2.5 km in these units as a result of temperatures that reach 350°C. Flooring the depression and outcropping to the northeast and southwest are volcanic, plutonic, and metamorphic rocks ranging in age from Pre-Cambrian to late Tertiary. A generalized heat flow of 2.5 heat flow units (hfu) for the Salton Trough is compared to a 1.5 to 2.5 hfu in the nearby fault-block ranges. On a regional scale it is suggested that the Salton Trough be viewed as the southwestern edge of a pervasive continental crust rift system that merges with the adjacent Basin and Range system, but this rifting has been masked by the right lateral transform movement of the San Andreas zone.

SALTON TROUGH - SELECTED REFERENCES - RIFT ZONE AND TRANSFORM FAULT TECTONICS

- ATWATER, T., 1970. "Implication of Plate Tectonics for the Cenozoic Evolution of Western North America," Geol. Soc. Amer. Bull., V. 81, pp. 3513-3536.
- BABCOCK, E., 1974. "Geology of the Northeast Margin of the Salton Trough, Salton Sea, California," Geol. Soc. Amer. Bull., V. 85, pp. 321-332.
- BAILEY, T.P., 1977. A Hydrogeological and Subsurface Study of Imperial Valley Geothermal Anomalies, California, Dept. Geological Sciences, University of Colorado, Boulder, Colorado, unpublished report, 101 p.
- BATIZA, R., 1978. "Geology, Petrology and Geochemistry of Isla Tortuga; A Recently Formed Tholeiitic Island in the Gulf of California," Geol. Soc. Amer. Bull., V. 89, pp. 1309-1324.
- BIEHLER, S., 1964. Geophysical Studies of the Salton Trough of California, unpublished Ph.D. thesis, California Inst. Technology, Pasadena.
- \_\_\_\_\_, 1971. "Gravity Studies in the Imperial Valley," in Cooperative Geological-Geophysical-Geochemical Investigations of Geothermal Resources in the Imperial Valley of California, R. Rex, (Principal Investigator), University of California, Riverside, pp. 29-43.
- BISCHOFF, J.L., and T.L. HENYEV, 1974. "Tectonic Elements of the Central Part of the Gulf of California," Geol. Soc. Amer. Bull., V. 85, p. 1893.
- BLACK, H.T., 1975. A Subsurface Study of the Mesa Geothermal Anomaly, Imperial Valley, California, unpublished report, University of Colorado, Boulder, Colorado, 58 p.
- CHOUKROUNE, P., J. FRANCHETEAU, X. LE PICHON, 1978. "In situ Structural Observation Along Transform Fault A in the FAMOUS Area, Mid-Atlantic Ridge," Geol. Soc. Amer. Bull., v. 89, pp. 1013-1029.
- CROWE, B.M., 1978. "Cenozoic Volcanic Geology and Probable Age of Inception of Basin-Range Faulting in the Southeasternmost Chocolate Mountains, California," Geol. Soc. Amer. Bull., V. 89, pp. 251-264.
- ELDERS, W., R. REX, T. MEIDEV, P.T. ROBINSON and S. BIEHLER, 1972. "Crustal Spreading in Southern California," Science, V. 178, No. 4056, pp. 15-24.
- ELDERS, W.A. and S. BIEHLER, 1975. "Gulf of California Rift System and Its Implication for the Tectonics of Western North America," Geology, V. 3, No. 2, pp. 85-87.

- FRANCHETEAU, J., P. CHOUKROUNE, R. HEKENIAN, X. LE PICHON and H.D. NEEDHAM, 1976. "Ocean Fracture Zones Do Not Provide Deep Sections in the Crust," Can. J. Earth Sci., V. 13, pp. 1223-1235.
- FUIS, G. and others, 1976 to 1978. "Preliminary Catalogue of Earthquakes in the Northern Imperial Valley, California," U.S. Geological Survey Open File Reports 77-694, 77-869, 77-431, 78-74, 78-671 and 78-673.
- GARFUNKEL, Z., 1973. "History of the San Andreas Fault as a Plate Boundary," Geol. Soc. Amer. Bull., V. 84, pp. 2035-2042.
- GASTIL, R.G., R.P. PHILLIPS and E.C. ALLISON, 1975. "Reconnaissance Geology of the State of Baja California," Geol. Soc. Amer. Memoir 140, 170 p.
- GOYAL, K., 1978. Heat and Mass Transfer in a Saturated Porous Medium with Application to Geothermal Reservoirs, Ph.D. thesis, University of Colorado, Boulder.
- HENYEEY, T. and J. BISCHOFF, 1973. "Tectonic Elements of the Northern Part of the Gulf of California," Geol. Soc. Amer. Bull., V. 84, pp. 315-330.
- HILEMAN, J.A., C.R. ALLEN and J.M. NORDQUIST, 1973. Seismicity of the Southern California Region 1932 to 1972, Seismological Laboratory, Cal. Inst. Techn., Pasadena, California, 94 p.
- KARIG, D. AND W. JENSKY, 1972. "The Proto Gulf of California," Earth and Planet Sci. Letters, V. 17, pp. 169-174.
- KASSAMEYER, P., L. YOUNKER AND J. TEWKY, 1978. Draft Report: Salton Sea Geothermal System: II. Thermal Source Modeling and Resource Assessment, Lawrence Livermore Laboratory, 30 p.
- LACHENBRUCH, A.H., in press, "Heat Flow in the Basin and Range Province and Thermal Effects of Tectonic Extension," PAGEOPH, 15 p.
- LARSON, R.L., 1972. "Magnetic Anomalies and Fracture Zone Trench in the Gulf of California," Geol. Soc. Amer. Bull., V. 83, pp. 3361-3368.
- LAWVER, L.A., 1976. Heat Flow in the Gulf of California, unpublished Ph.D. thesis, University of California, San Diego, 76 p.
- LISTER, C.R.B., 1975. "Qualitative Theory on the Deep End of Geothermal Systems," 2nd U.N. Conference on Develop. Geothermal Resources, San Francisco, California, pp. 459-463.
- LOELTZ, O.J., B. IRELAN, J.H. ROBINSON and F.H. OLMSTEAD, 1975. "Geo-hydrologic Reconnaissance of the Imperial Valley, California," U.S. Geol. Survey Prof. Paper 486-K, 55 p.
- MEIDAV, T. and R. REX, 1970. Investigation of Geothermal Resources in the Imperial Valley, Inst. Geophy. and Plant. Physics, University of California, Riverside, 54 p.

- MENARD, H. and T. ATWATER, 1969. "Origin of Fracture Zone Topography," Nature, V. 222, pp. 1037-1040.
- MORTON, P., 1977. Geology and Mineral Resources of Imperial Valley, California, California Division Mines and Geol. County Report No. 7, Sacramento, California, including geologic map compiled in 1966, 104 p.
- PALMER, T., J.H. HOWARD and D.P. LANDE, 1975. Geothermal Development of the Salton Trough, California and Mexico, Lawrence Livermore Laboratory, University of California, 11 p.
- PUENTE CRUZ, IGNACIO, 1978. Geology of the Cerro Prieto Geothermal Field, (Abstract), in Abstract Volume of First Symposium on the Cerro Prieto Geothermal Field, Lawrence Berkeley Laboratory, University of California, Berkeley, California, p. 6.
- REICHLER, M. and I. REID, 1977. "Detailed Study of Earthquake Swarms for the Gulf of California," Bull. Seismol. Soc. Amer., V. 67, pp. 159-171.
- SHARMAN, G., 1976. The Plate Tectonic Evolution of the Gulf of California, unpublished Ph.D. thesis, University of California, San Diego, 86 p.
- SHARMAN, G.F., M.S. REICHLER and J. BRUNE, 1976. "Detailed Study of Relative Plate Motion in the Gulf of California," Geology, pp. 206-210.
- SHARP, R.V., 1975. "En Echelon Fault Patterns of the San Jacinto Fault Zone, in, Crowell, (Ed.), Cal. Div. Mines and Geol. Spec. Rpt. #118, pp. 147-152.
- SIMONIAN, K.O. and K.G. GASS, 1978. "Arakapas Fault Belt - A Fossil Transform Fault," Geol. Soc. Amer. Bull., V. 89, pp. 1220-1230.
- STIELTJES, L., 1975. "Research for a Geothermal Field in a Zone of Oceanic Spreading - An Example of Asal Rift," in, Second U.N. Symposium on Develop. Geothermal Resources, San Francisco, pp. 613-623.
- SYLVESTER, A.G. and R.R. SMITH, 1976. "Tectonic Transpression and Basement-Controlled Deformation in San Andreas Fault Zone, Salton Trough, California," Amer. Assoc. Petrol. Geol. Bull., V. 60, pp. 2081-2101.
- van de KAMP, P.C., 1973. "Holocene Continental Sedimentation in the Salton Basin, California - A Reconnaissance," Geol. Soc. Amer. Bull., V. 84, pp. 827-848.



\_\_\_\_\_, 1978. Geology of the East Mesa KGRA, Draft Final Report to Lawrence Berkeley Laboratory, Geothermal Reservoir Engineering Group.

WHITMARSH, R.B. and A.S. LAUGHTON, 1975. "The Fault Pattern of a Slow-Spreading Ridge Near a Fracture Zone," Nature, V. 258, pp. 509-510.

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