STRUCTURAL FEATURES OF THE SALTON TROUGH AS SEEN FROM SKYLAB

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In light of recent geological and geophysical evidence of plate tectonics, it now appears that the Gulf of California was formed by the separation of the peninsula of Baja California from mainland Mexico. According to the plate tectonics concept, the separation resulted from crustal spreading caused by lateral drifting of the Pacific plate from the North American plate with the two plates separated by a divergent plate boundary. Crustal spreading, beginning in Middle to Late Cenozoic (10 to 26 million years ago), extends inland from the Gulf of California through the Mexicali, Imperial, and Coachella Valleys. Much of the crustal spreading, along the landward extension known as the Salton Trough, seems to be initiated along extensive *en echelon* right-lateral strike-slip faults of which the San Andreas is the best known.

The Salton Trough has been extensively mapped on the ground by detailed geologic methods, and a large amount of ground-based geophysical data also has been collected. The result has been detailed mapping of many local fault zones, and subsequently these data have been pieced together by many investigators. However, a regional overview can now be obtained from high quality small scale satellite imagery which was not available to earlier investigators. Large scale structural patterns are often so subtle that they are lost entirely when many conventional air photos are assembled into a photo mosaic because of variations in negative density, exposure of prints, and developing. When detailed geologic maps of a structural belt are examined, tectonic lineaments may not be traceable over long distances.

SKYLAB IMAGERY

Skylab imagery has proven to be very useful in examining large-scale geotectonic regions in order to supplement detailed field mapping. The new perspective which earth-orbital photography provides is unattainable by low altitude photo-geologic procedures or ground-based geologic methods. With Skylab imagery, the Salton Trough appears as a single structural unit in the regional context of neighboring units: the Peninsular Ranges and the Mojave-Sonora Desert. Much of its complexity is simplified by the view of the entire area provided from an earth-orbital platform. The high resolution of Skylab imagery also lends itself to detailed photo-geologic studies.

Examination of four adjoining Skylab frames of the Salton Trough (taken 2 June 1973) allows regional tracing of important tectonic lineaments (faults, fractures, fault controlled valleys, and sand dunes) and a description of the entire region's structural features. Such linear features are expressions of the basement structure buried beneath the landscape.

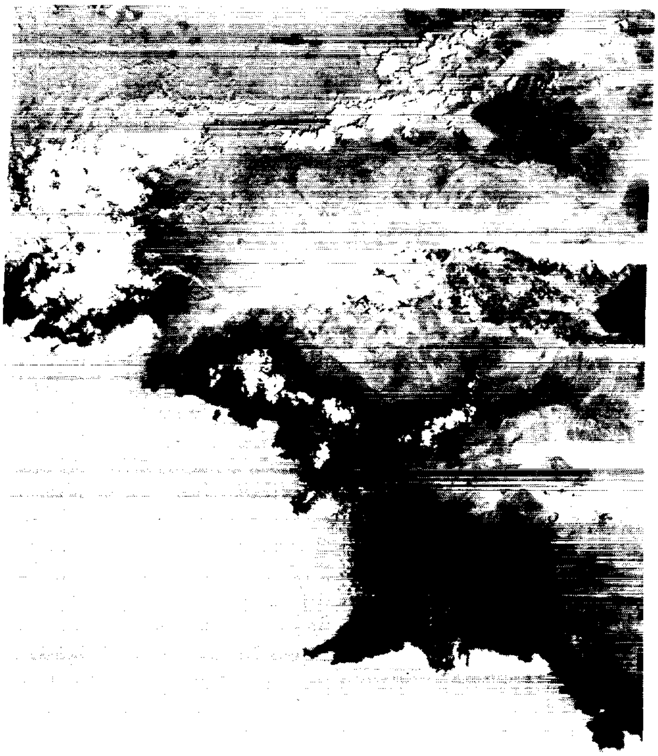
Panchromatic 70 mm Skylab images were enlarged to a scale of approximately 1:250,000 and used as base maps. The black and white enlargements were compared with color and color infrared imagery in order to better observe the lithologic pattern which frequently has bearing on the structural pattern. As mapping proceeded the photomaps were compared with published geologic maps of similar scale that had been prepared by ground-based field mapping and by using low altitude aerial photography.

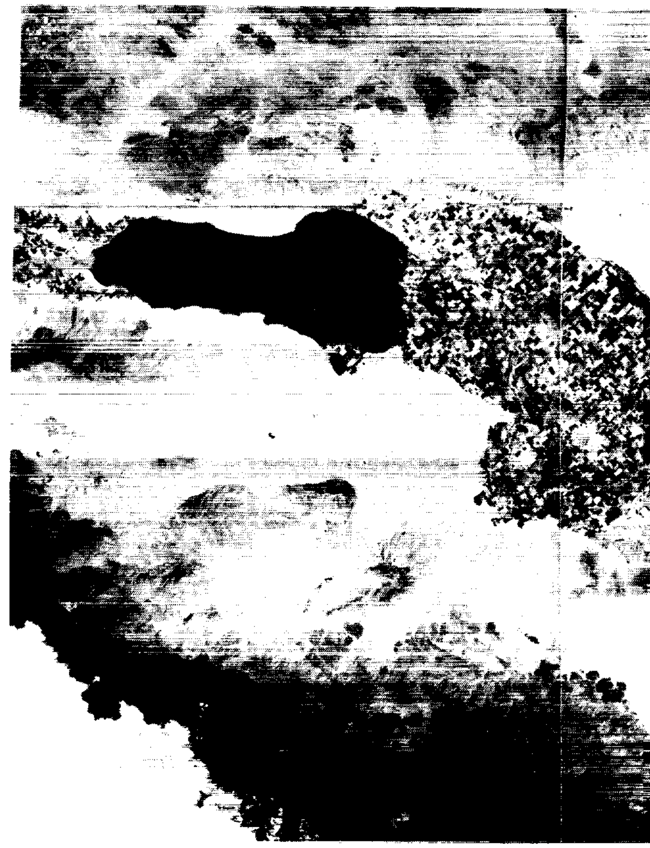
STRUCTURAL FEATURES

The general geologic setting of the Salton Trough may be described as a large, complex, southeast trending graben, down-dropped between the San Andreas fault zone on the east and the Elsinore fault zone on the west. The graben itself subsequently has been cut by *en echelon* southeast-trending strike-slip faults of right-lateral offset. The San Andreas fault has experienced right-lateral offset of major proportion in the geologic past, evidenced by the stratigraphic mismatch of rocks on either side of the fault for many miles. The degree of right-lateral offset along the Elsinore fault remains unclear; large canyons, which appear to cross the Elsinore fault with little if any lateral displacement, may be observed on the imagery. In the Salton Trough outcrops of Miocene continental conglomerates and gypsum beds lie unconformably on Mesozoic granitic rocks of the southern California batholith and lower Mesozoic to pre-Cambrian metamorphic rocks. Interbedded continental and marine sediments of Pliocene age overlying Miocene sediments, are capped by continental sediments of Quaternary age. The sediments of the Salton Trough are locally intruded by Pliocene and Pleistocene volcanics, with volcanism being much more common in the Baja and Sonora portions. On the west side of the Elsinore fault lie the Peninsular Ranges, primarily composed of Jurassic and Cretaceous intrusives of the southern California batholith, intruded into Triassic and older metasediments. East of the Salton Trough lie the more tectonically stable Mojave and Sonora Deserts, containing a stratigraphic column of much longer duration than that of the Salton Trough.

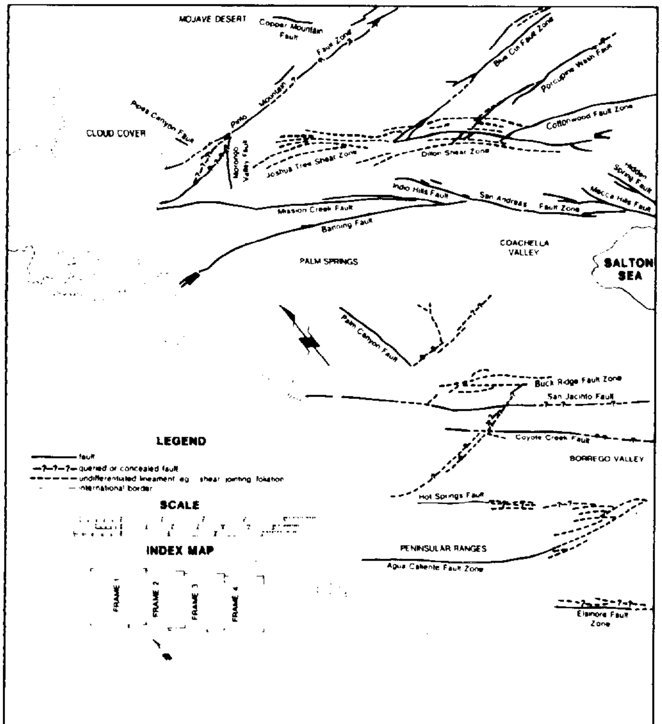
With regard to the structural features of the area, two predominant trends of faulting may be observed: southeast-northwest and east-west. The southeast-northwest trending faults are primarily rift faults of right-lateral strike-slip displacement, frequently supplemented by dip-slip of rotational displacement. As mentioned previously, the Salton Trough represents a graben that has been downthrown between the San Andreas and Elsinore faults. These two faults, rather than being single lineaments, are zones of parallel and interconnected faults and fractures. The graben is cut by five major zones: (1) the Elsinore fault zone; (2) the Agua Caliente-Hot Springs fault zone; (3) the Coyote Creek-Cucapa fault zone; (4) the San Jacinto-Superstition Mountain-Cerro Prieto fault zone; and (5) the Banning-Mission Creek-San Andreas fault zone. Smaller individually named branch faults splay from the major faults of each zone; for example, the Indio Hills fault and Mecca Hills fault of the San Andreas fault zone.

East-west trending faults are transverse, some displaying left-lateral displacement. The transverse faults constitute large fault zones in the northeastern portion of the area where they extend eastward from the eastern side of the Salton Trough into the Mojave Desert. The Pinto Mountain, Blue Cut, Porcupine Wash, and Cottonwood fault zones are in this category and seem to be directly associated with crustal spreading and rifting processes. A possible hypothesis to explain their origin is that they are second order left-lateral shear faults belonging to a conjugate set, the first-order controlling faults of the set being the right-lateral southeast trending rift faults.

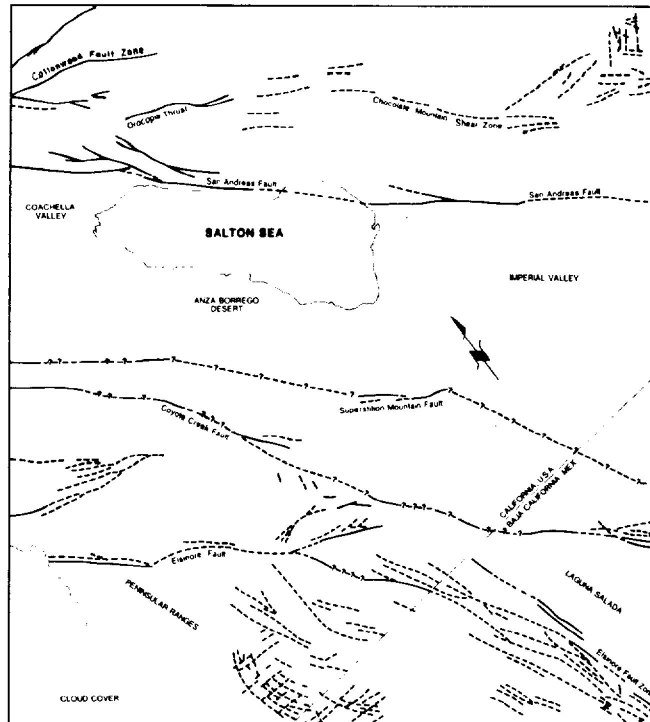




Map Frames 1-4 are structural sketch maps interpreted from Skylab images, Salton Trough



FRAME 1



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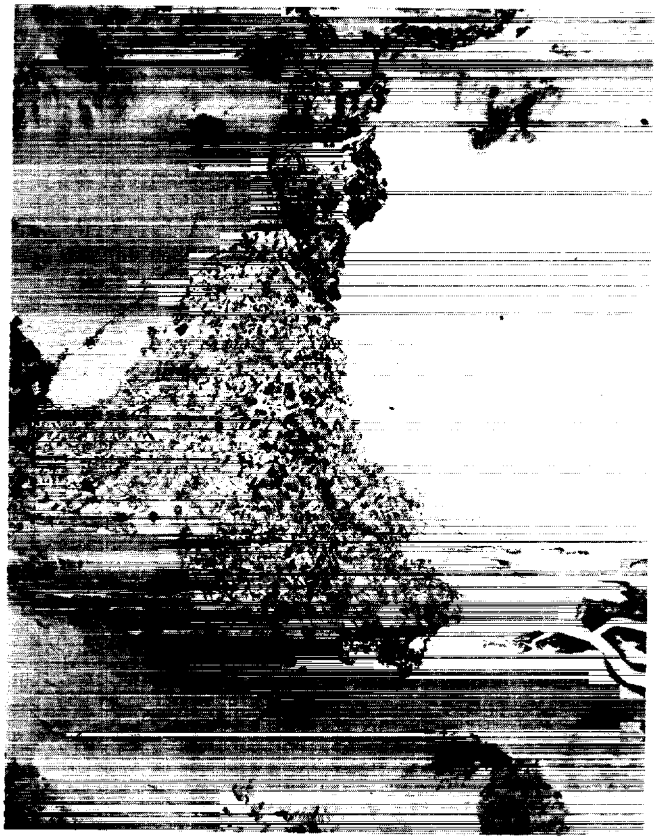

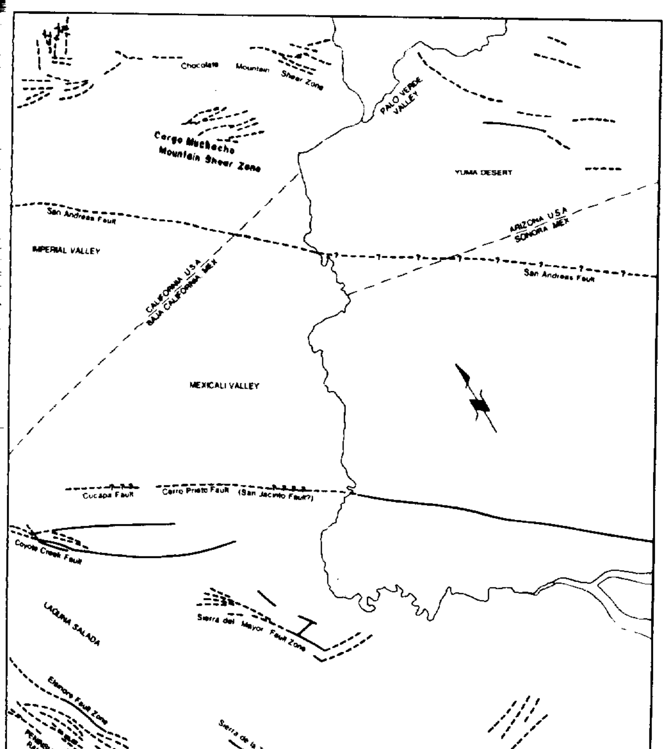

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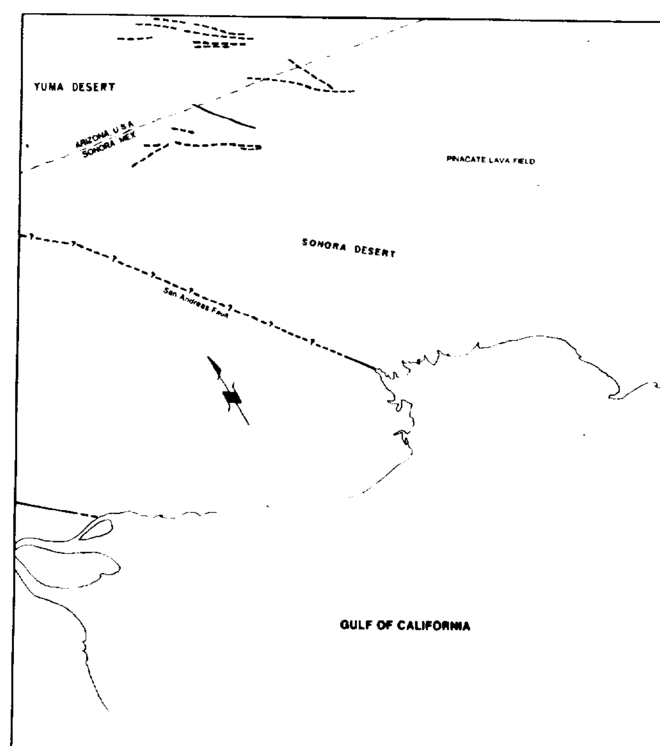

FRAME 4

In the southern portion of the Salton Trough, transverse phenomena are limited to smaller fracture systems or shear zones rather than well-developed linear fault zones. Transverse fractures may be detected in the Chocolate Mountains, Cargo Muchacho Mountains, Sierra Pinta, Sierra del Mayor, and parts of the lower Peninsular Ranges. In some cases the fractures are related to regional jointing and foliation patterns in the igneous-metamorphic basement complex, particularly in the Peninsular Ranges. Here the near-concentric configuration of some lineaments are probably surface manifestations of ring dikes or cone sheets. In this case these structures would have originated with the emplacement of the southern California batholith (65 to 136 million years ago) and would be much older than those structures originating with Cenozoic crustal spreading and rifting.

NEW DATA DETERMINED FROM SKYLAB IMAGERY

Many previously unmapped lineaments and connections of existing lineaments are visible on Skylab imagery of the Salton Trough, as shown on structure map frames 1-4, which correspond to panchromatic Skylab photo frames 1-4.

FRAME 1:

Fractures in the Dillon shear zone and Joshua Tree shear zone are shown to be more numerous and longer than previously known. The Porcupine Wash fault continues its westward trend, merging with the Dillon shear. The Cottonwood fault is seen as a major lineament rather than a few small unconnected faults; an eastward trending lineament splays perpendicularly from the south end of the Palm Canyon fault; the Hot Springs fault connects to the southeast with the Agua Caliente fault.

FRAME 2:

The Cottonwood fault extends further east than was previously suspected; an unmapped lineament at the south end of the Salton Sea splays into the San Andreas fault zone; the Coyote Creek fault extends to the Cucapa fault east of Laguna Salada in Baja California; the Elsinore fault zone extends along the eastern edge of the Peninsular Ranges west of Laguna Salada in Baja California.

FRAME 3:

Previously unmapped fracture systems are visible in the Chocolate Mountains and Cargo Muchacho Mountains; unmapped lineaments are visible in the Yuma Desert; the extent of the Sierra del Mayor fault zone is increased.

FRAME 4:

Previously unmapped lineaments are observed in the Yuma and Sonora Deserts. Photo frames 2, 3, and 4 indicate that the San Jacinto fault may extend from its mapped southern extremity west of the Salton Sea to the Superstition Mountain fault and southward to the Cerro Prieto fault, although surficial evidence is lacking. The San Andreas fault may extend southward into the rift bay east of the Colorado River delta. Connection of these faults is questionable, as shown on the structural map.

CONCLUSION

When viewed on Skylab imagery the tectonic framework of the Salton Trough may be seen more clearly than ever before. The high resolution photography allows the benefit of viewing large-scale regional patterns on small-scale imagery. Large-scale structural patterns can be seen in striking clarity when viewed in this regional context. Some of these patterns had been only suspected before Skylab imagery was available. Structural sketch maps compiled from each frame of the photo imagery clearly delineate observable lineaments, many being extended beyond their prior ground-evaluated extremities.

REFERENCES

Clarke, Anthony O., 1973, A remotely sensed examination of the tectonic framework of the Mojave Desert north of San Bernardino, California, an integrated study of Earth resources in the state of California based on ERTS-1 and supporting aircraft data: Space Sciences Laboratory, University of California, Berkeley, NASA NAS 5-21827.

Cooper, Arthur G., and others, 1956, Geologia y paleontologia de la region de Caborca, norponiente de Sonora: 20th International Geological Congress, Mexico, D.F.

Elders, Wilfred A., and others, 1972, Crustal spreading in southern California: *in* Science, v. 178, p. 15-24, October.

Gastil, Gordon, Phillips, Richard, and Allison, Edwin, 1974, Reconnaissance geology of the state of Baja California: Geological Society of America Memoir 140, Map Sheet A, scale 1:250,000, Boulder, Colorado.

Jennings, Charles W., 1967, Geologic map of Califonria, Salton Sea sheet (scale 1:250,000): California Division of Mines and Geology.

Lowman, Paul D., 1969, Apollo 9 multispectral photography, geologic analysis: Goddard Space Flight Center, Greenbelt, Maryland.

Rogers, Thomas H., 1967, Geologic map of California, San Bernardino sheet (scale 1:250,000): California Division of Mines and Geology.

Rogers, Thomas H., 1965, Geologic map of California, Santa Ana sheet (scale 1:250,000): California Division of Mines and Geology.

Strand, Rudolph G., 1962, Geologic map of California, San Diego - El Centro sheet (scale 1:250,000): California Division of Mines and Geology.

Wilson, Eldred D., 1960, Geologic map of Yuma County, Arizona (scale 1:375,000): Arizona Bureau of Mines. ⚒

LAS VEGAS TO DEATH VALLEY GUIDEBOOK

A guidebook with road log of the geology, geography, and history encountered on a trip from Las Vegas to Death Valley has been published by the Nevada Bureau of Mines and Geology.

Prepared as a field trip guide for the American Institute of Mining, Metallurgical and Petroleum Engineers (AIME) meeting in Las Vegas, the publication includes features of interest to both the technically trained person and layman.

The road log, prepared by Keith G. Papke and John H. Schilling of the Nevada Bureau of Mines and Geology, takes the traveler from downtown Las Vegas north to Lathrop Wells, thence to Death Valley Junction, Furnace Creek, and return by way of Shoshone and Pahrump, a distance of 304 miles.

The publication includes excerpts from a booklet on Death Valley published by the National Park Service; an article on borate deposits in the Death Valley region by James M. Barker and Jeffrey L. Wilson of Tenneco Mining, Inc.; a description of Tenneco Oil's colemanite milling operations near Lathrop Wells by Richard A. Walters of Tenneco Oil Co.; and a summary of information on the Grantham Talc Mine in the southern part of Death Valley by Keith Papke, who also served as tour guide for the AIME field trip.

Listed as Report 26, the "Guidebook: Las Vegas to Death Valley and Return," is available for $3.00 from the Nevada Bureau of Mines and Geology, University of Nevada, Reno, 89507. ⚒