CC/NUMBER 27
JULY 2, 1990

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Hsü K J. Principles of mélanges and their bearing on the Franciscan-Knoxville paradox. *Geol. Soc. Amer. Bull.* 79:1063-74, 1968.
[Swiss Federal Institute of Technology, Zurich, Switzerland]

This article points out that the rocks in shear zones induced by 10^3 or 10^4 km displacement are a mixture of fragmented slabs embedded in a ductily deformed matrix. New principles are formulated as the guideline for studying such mélanges. [The *SCI*® indicates that this paper has been cited in over 130 publications.]

Mélanges and Non-Smithian Stratigraphy

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February 27, 1990

Scientific endeavors are personal. I worked for Shell Oil Company, lived in Texas, and married a Swiss. My late wife, Ruth, liked oceans and mountains. I maneuvered, therefore, to start a project on the Franciscan rocks of the California Coast Ranges in 1963.

The Franciscan used to be called basement; they are "hard" rocks that rarely have porosity to store hydrocarbons. Petroleum geologists do not study basement. After successes with my first two projects, however, my credibility with the management was such that I could persuade them of the relevance of Franciscan geology to oil exploration. The family moved to Morro Bay, California, and Ruth became a beachcomber for six months.

The discovery I was to make belies the common wisdom that hard work produces success. I followed the dictim and started a tedious fight in the spring of 1963 against sagebrush on steep mountainsides under the California sun. After weeks of hardship, I was rewarded with confusion. Discouraged, I took a working day off and went to the beach with the family. The Franciscan rocks are exposed almost everywhere on the seaside south of Monterey. We sat on Franciscan sandstone when we had our picnic lunch. I did not have to look very far to see that the three laws of Smithian stratigraphy are violated: The harder (or more brittle) sandstone layers are broken into millions of pieces, large and small, scattered in a pervasively sheared muddy matrix. There is no lateral continuity of the broken formations. The individual fragmented slabs have been shoved on top of one another in a chaotic fashion, making the "law of superposition" irrelevant. Furthermore, none of the rocks on the beach has any fossils, and the few fossils found in Franciscan rocks elsewhere do not help very much to order the chaos that is Franciscan.

The discovery was made at one glance, but there was much afterthought.[1] The logic is clear: We have to have a non-Smithian stratigraphy. Conventional geological mapping and the stratigraphy of William Smith assume coherence of rock formations. Strata could be cut up and displaced along the faults, but those bounded by faults retain their coherence. The Franciscan rocks are, in contrast, incoherent, a mélange as the French would say.

As I found out later, E. Greenly[2] discovered in 1919 that rock bodies in Anglesey are disintegrated by shearing, but neither he nor others appreciated the significance of that discovery: We have to change our outlook of the world. Geologists used to be "fixists," believing that rocks on continents or ocean floors were always fixed where they are now found. My discovery removed this "fixistic" constraint: The Franciscan rocks have been pervasively sheared, and the total displacements along the innumerable shear planes of the mélange add up to 10^3 or 10^4 km.

Nineteen sixty-three was the year of a great revolution in earth science when F.J. Vine and D.H. Matthews[3] formulated the seafloor-spreading theory, leading to later developments of the plate-tectonic theory. They postulated displacement of the Pacific seafloor of 10^4 km during the last 10^8 years. I did not know then that I was gathering evidence to verify the corollary of the new paradigm: Wide expanse of the Pacific seafloor has been tucked under the Coast Range and fragments of ocean lithosphere have been left behind, embedded in pervasively sheared matrix to form the Franciscan mélange.

My 1969 paper was to formulate a set of new principles, the principles of mélanges, and to propose this non-Smithian stratigraphy as a guideline for studies of mélanges that are found in mountain ranges all over the world. For this contribution to the "stratigraphy of mountains," I was to receive the Wollaston Medal in 1984, the highest award of the Geological Society. Prior to that, however, I had to face establishment resistance against the new idea. The original manuscript was rejected by a referee, and it was accepted by the journal editor only after I agreed to a compromise to have it published in the "Geological Note" section for trivial communications. For more than a decade, I was pictured as a Don Quixote waving my lance against a windmill that was the US Geological Survey. The very nonacceptance, ironically, increased the number of citations: Young geologists adopting the non-Smithian stratigraphical principles to unravel the geologic history of mountains still have to cite the article, two decades after the discovery, because the word *mélange* is found in few of the current textbooks.

1. **Hsü K J.** A basement of mélanges: a personal account of the circumstances leading to the breakthrough in Franciscan research. (Drake E T. & Jordan W M, eds.) *Geologists and ideas: a history of North American geology.* Boulder, CO: Geological Society of America, 1985. Vol. 1. p. 47-64. (Cited 5 times.)
2. **Greenly E.** *The geology of Anglesey.* London: His Majesty's Stationery Office, 1919. 980 p. (Cited 115 times since 1945.)
3. **Vine F J & Matthews D H.** Magnetic anomalies over ocean ridges. *Nature* 199:947-9, 1963. (Cited 480 times.)

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