

RIGID-PLASTIC INDENTATION AND TECTONIC EVOLUTION OF THE
ALPINE SYSTEM IN EUROPE.

Paul TAPPONNIER, Lab. Géologie Structurale, place E. Bataillon
USTL 34060 Montpellier Cédex.

ABSTRACT

The distribution in space and succession in time of the major tectonic events in the Western Alpine system since the Jurassic is interpreted as the result of progressive oblique indentation of Europe by peninsulas of the African continent.

RESUME

La répartition géographique et l'enchaînement dans le temps des différents épisodes tectoniques majeurs en Méditerranée (des Balkans à Gibraltar) sont interprétés à l'aide d'un formalisme nouveau (Analogie Rigide plastique) développé pour l'étude des déformations intraplaques qui résultent des collisions continentales, comme par exemple en Asie Nord Himalayenne. La cause principale des déformations Alpines en Méditerranée depuis le jurassique est le poinçonnement oblique et progressif de l'Europe par divers promontoires de l'Afrique.

The tectonics of the alpine chains in the western mediterranean are related to the slow convergence between the African and European continents since the Jurassic. In this context situations of continental interactions and collisions have arisen which show many similarities with situations related to the India-Eurasia collision and the large scale continental tectonics it has caused in Asia (1). We therefore suggest that new methods which are being developed for the analysis of intraplate tectonics in Asia (2) are also adapted to the study of the Alpine system in the Mediterranean. These methods imply a rigid-plastic behavior of the continental lithosphere and use slip-line field analysis to estimate the stress field in the lithosphere. We believe that :

- 1- The existence of ocean basins which is the main difference between the mediterranean and continental Asia may not give rise to major difficulties. Because these basins are small and have a complex shape, subduction of oceanic lithosphere at their margins may be difficult. They may therefore behave like rigid blocks (such as the shields in Asia) and transmit the forces that are exerted at their boundaries.
- 2- A most important requirement is to explain in a coherent way the distribution in space and the succession in time of the different tectonic events and phases. From the Balkans to Gibraltar, these events should be interrelated.

Most of the Tectonics of the western mediterranean since the late Jurassic can then be viewed as a combination of three basic processes :

1- The first one is an oblique and progressive "indentation" of Europe by peninsulas of the African continent. The major indenters are limited by important strike slip fault systems. The major system, oriented NE-SW extends from the Rif mountains to the Carpathians, over a total length of more than 2000 km. Segments of it have been activated, mostly in a left lateral sense, at different epochs since the Jurassic. It separates to the West, the French-Austrian Alps, and the Betic-Gibraltar arc.

A smaller, right-lateral fault-system separates to the East the Balkan mountains, and the Egean arc from the Dinarids and the Carpathians. The maximum shortening in the whole Western Alps (from 500 km to 1000 km since the Jurassic) has occurred between these two fault systems in the Dinarids, Carpathians and Appenines.

2- The second process is a consequence of indentation : it is a "lateral flow" of the continental lithosphere along large strike-slip faults, which prevents excessive crustal thickening in front of the indenter. This flow entrances subduction of ocean basins adjacent to the indenter, and thus causes the formation of small lateral subduction arcs. We believe that the formation at different epochs of the four major syntaxis in the Western Alpine system (French Alps and Gibraltar arc to the West, Transylvanian and Tyrrhenian arc to the East) is related to this process.

3- The third Process is a "cracking" of the lithosphere (formation of graben, and Alcaline basalt vulcanism) which can originate at major strike slip faults. The cause of this crustal thinning and break up is a stress state analogous to "secondary tension" (known in mechanical engineering) which develops in the rigid-plastic media for same indentation geometries and boundary conditions. We think that the Oligocene rifting in France and Germany, the quaternary rifting and alkaline basalt volcanics (Etna) in Calabria and Sicily, and the opening of the Provencal ocean basin is due to this process. At a larger scale, the opening of the North Atlantic in the Eocene, may also have a similar origin, and Would then appear as a direct consequence of the progressive indentation of Africa into Europe.

(1) - P. Molnar and P. Tapponnier : "Cenozoic Tectonics of Asia : Effects of a continental collision. " Science, 189, 419-426, 1975.

(2) - P. Tapponnier and P. Molnar : "Slip line Field theory as a quantitative method for understanding large scale continental Tectonics." Nature, 1976, in press.