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Report on a meeting of the Research Group on Recent Brittle Tectonics in the Western Mediterranean area

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THE *Gruppo di Ricerca sulla Tettonica Fragile Recente nel Mediterraneo Occidentale* has, since 1981, been undertaking and co-ordinating research into aspects of brittle neotectonics in the Western Mediterranean region. The group, led by Mario Boccaletti of the University of Florence, comprises a nucleus of workers from Italian universities who have more recently been joined by Spanish and Greek colleagues operating out of their home universities. Financial support for field work and meetings is provided by the Italian Education Ministry (*Ministero Pubblica Istruzione*).

The primary purpose of the group is to encourage the investigation of the brittle deformation of the Western Mediterranean region since the late Miocene, and in particular the history of its Neogene–Quaternary stress fields. For the purposes of providing organizational focus three subprojects have been constituted. They are: (1) the Arc of Gibraltar subproject (in collaboration with Spanish colleagues); (2) the Maghreb (Tunisia)–Sicily region subproject; and (3) the central and northern Apennines subproject. The theme of a subproject in collaboration with Greek geologists is currently being formulated.

The research strategy adopted by the majority of members in the group is multifaceted, with an emphasis on integrating information gained from earthquake seismology, surveys of mesoscale-structures and lineament analysis with that collected during regional geological and geophysical mapping.

A conclusion of general interest that has resulted from the Maghreb–Sicily subproject is that contemporary directions of horizontal compression and extension can be determined not only from *in situ* stress measurements and fault-plane solutions of earthquakes, but also from the analysis of brittle mesostructures developed during the late Pleistocene and Holocene (e.g. Cello *et al.* 1982, Boccaletti 1983, Boccaletti *et al.* 1984). The most valuable mesostructures for determining kinematics are considered to be stylolites with well-developed interlocking teeth, and mesofaults, especially those bearing striations. Bernini & Lina (1984) have published a computer program that permits the graphic display of fault cyclographic traces, with or without accompanying striae poles. Because well-dated Neogene–Quaternary sequences are relatively well developed in Calabria and Sicily the neotectonic (*sensu lato*) stress history of the region inferred from mesostructures is more refined than customary. This has allowed Boccaletti *et al.* (1984) to identify five episodes: late Tortonian–early Pliocene; medial Pliocene; late Pliocene–early Pleistocene; medial Pleistocene; and late Pleistocene–Holocene. Each episode is characterized by different directions of compression and extension and significant spatial variations of direction occurred within episodes. Notable regional appraisals of the neotectonics of the central and northern Apennines based on Landsat image analysis, regional mapping, earthquake seismology and seismic reflection profiles are those of Bartolini *et al.* (1982), Boccaletti *et al.* (1985) and Castellarin *et al.* (1985), whose maps and sections provide much new information for those requiring a source for syntheses. A well-illustrated field guide (in English) by Bernini *et al.* (1986) to the Pontremoli and Fornova areas of Tuscany, guides visitors to sites where structures related to extensional collapse in the internal Apennines may be inspected and contrasted with roughly contemporaneous compressional structures in the external Apennines adjacent to the buried, but active, thrust front beneath the Po basin molasse. A regional overview of the tectonics of the entire western Mediterranean area is presented in a new 1:250,000 map compiled by Boccaletti *et al.* (1986).

The 1986 discussion meeting of the 'Brittle Neotectonics' Group was held at the University of Florence on Thursday 17 April, and was, for overseas delegates, followed the next day by an excursion to the Northern Apennines. The leaders were *M. Bernini, G. Papani &*

P. Vescovi of the Institute of Geology at the University of Parma. Copies of their (Bernini *et al.* 1986) field guide and introduction to the tectonics of the region can be obtained from them at the Istituto di dell'Universita di Parma, Via Kennedy, 8, 43100 Parma, Italy.

The discussion meeting comprised two sessions: an opening one in which three overseas visitors who are not members of the group gave presentations on themes of general methodological interest, and a second session comprising nine lectures by members of the group. Authors and papers were:

Session 1

P. L. Hancock (Bristol). Premises and procedures in brittle tectonics.

J. L. Mercier (Paris). Neogene to present evolution of the state of stress in the Himalaya and Tibet: compressional and extensional events in the internal zones.

A. Nur (Stanford). Block rotations in transcurrent regimes.

Session 2

D. Mountrakis, A. Killas, S. Pavlides, D. Patras & N. Spyropoulos. Structure of the Internal Hellenides and their role in the evolution of the eastern Mediterranean.

Ph. Voidomotis, S. Pavlides & D. Kondopoulou. Late Cenozoic geodynamics of Northern Greece.

M. Boccaletti, R. Gelati, A. C. Lopez-Garrido, G. Papani, J. Rodriguez-Fernandez & C. Sanz de Galdeano. Neogene–Quaternary structural evolution of the Betic Cordillera.

M. Boccaletti, G. Cello & L. Tortorici. Neogene strike–slip tectonics in central Tunisia.

A. Fesce & A. Pini. Analysis of mesoscopic structures in the intra-Apenninic and pede-Apenninic Pliocene of the Bologna area.

M. R. Mannori. Analysis of mesoscopic structures in Plio-Pleistocene sediments of the Santerno area.

M. Bernini & G. Papani. Structure of the Apenninic margin between Stirone and Enza.

M. Boccaletti, A. Cerrini Feroni, M. R. Mannori, P. Martinelli & F. Sani. Mesostructures in the Pleistocene deposits of the lower Cecina valley, central Tuscany.

F. Calamita, S. Mastrovincenzo & G. Invernizzi. Mesostructural analysis of Mio-Pliocene deposits of the outer Marche area.

During the presentation of papers, their discussion and a closing open forum a number of general themes attracted attention. *Hancock* and *Mercier* considered whether it was reasonable for those attempting palaeostress analysis from mesofaults and allied structures to assume that brittle behaviour was the dominant mode during deformation. They concluded that if the domain (i.e. station) to be analyzed is volumetrically small, say less than 10^6 m^3, structurally homogeneous and contains completely the sampled structures, then, providing it is known that only small strains occurred within fault-bounded blocks, acceptance of the premise permits palaeostress axis orientations to be determined approximately. Additional limitations on the validity of numerical methods for determining stress tensors from striated fault planes were also outlined by Mercier who, with coauthors, has documented them in Sébrier *et al.* (1985). It was also agreed that although striated faults generally provide the most rewarding data sets their interpretation may need to be constrained or augmented by inferences derived from veins, stylolites and joints. The analysis of joint patterns is especially important in platform settings lacking abundant faults and allied kinematic indicators (e.g. Hancock 1985).

Another topic which attracted wide interest was *Nur*'s proposal that in regions with pervasive transcurrent faulting large angular rotations of blocks are quite common. In particular, the rotations computed from the senses of fault slip and spacing agree well with palaeomagnetic rotations. Such block rotations could significantly modify the interpretation of regional tectonics. Similarly, in graben fields, dominated by normal faults, significant rotations about horizontal axes can occur. *Boccaletti, Cello & Tortorici*'s description of strike–slip faults of unlike trend and opposite sense of motion occurring in different and not overlapping parts of Tunisia south of the Tellian Atlas stimulated reporting of other apparently conjugate strike–slip fault systems characterized by a domainal distribution of the fault trends. Determining the nature of domain boundaries in such terrains and between rotated blocks in transcurrent fault zones was identified as a topic for future research.

In the context of ideas about the tectonic evolution of the Apennines several conclusions provoked discussion. Of particular note was the proposal by *Boccaletti, Cerrina Ferroni, Mannori, Martinelli & Sani* that part of the internal (Tyrrhenian) domain in Southern Tuscany has experienced alternating episodes of shortening and extension since the Tortonian. Previously, the domain was thought to have been continuously in extension since the Messinian, in contrast to the more external (i.e. Adriatic) domains within which shortening has continued until the present. The direction of compression and extension in the internal zones during the Pleistocene was uniformly NE–SW, parallel to the direction of Pleistocene compression in the external zones.

The papers presented at the meeting will be published in a special 1987 issue of the Italian journal *Ateneo Parmense*; they will be edited by M. Boccaletti and G. Papani.

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