The second year of the MEBE Programme is now completed. The first two years were devoted to data acquisition through 26 scientific projects involving 11 research institutions from 6 European countries. During this period, not less than 350-400 weeks of fieldwork was carried out. About 130 scientists from 35 European institutions and 25 organizations from the Middle East participated in the Programme. During these two last years substantial new data were collected. In most of the MEBE study area, including Iran, Eastern Turkey, the Caucasus domain, Levantine region as well as Yemen, field activity in the last 10-20 years has been much reduced for various reasons. It follows that the scientific contribution of the MEBE Programme constitutes a significant increase of fresh data at a regional scale. Our results will represent a major contribution to new interpretations of the reconstruction of the regional tectonic evolution in the whole Middle East.

One major original aspect of our Programme consists of developing scientific activities in most of the countries of the study area, including Armenia, Georgia, Azerbaijan, and Iran. About half of the MEBE projects are located in Iran because several regions of this country are have important academic and exploration interest. In Iran we developed a very active and fruitful cooperation with the Geological Survey of Iran. This organization provided the logistical support for most of the MEBE teams working in Iran (i.e. the equivalent of almost one year of fieldwork).

After the two-year data acquisition period, it is time to begin synthesizing the results. Syntheses will develop through newly created MEBE working groups. These groups are either regional (Zagros, South Caspian Basin and Central Iran, Caucasus, Black Sea, Arabian Margins, Levant) or thematic (Stratigraphic comparisons, Lithospheric Cross-Sections) in scope. The present activities of these groups and some of the scheduled results are extensively illustrated in this MEBE News. Each synthesis will take as a basis the new information obtained from the relevant MEBE projects, as well as published data. A set of palinspastic reconstructions, including both tectonic and stratigraphic data, will be presented one year after the end of the Programme.

In addition to the synthetic products of the working groups, a data base will be created (ArcGis 9). It will contain the most interesting data collected during the Programme. (measurements, cross-sections, diagrams, maps, stratigraphic logs, fauna, etc.). This product will be available only to the MEBE sponsors. Other results will be presented at congresses and symposia, and in scientific papers in international journals with the authorization of the sponsors.

Eric Barrier  
Maurizio Gaetani
The tectonic history and the geodynamic processes governing it of the Black Sea, thought to have opened as a back-arc basin behind a subduction zone the record of which is now incorporated into the geology of Central Turkey, form the subject of MEBE’s Black Sea Working Group.

The Working Group combines five MEBE projects. Four of these involved new geological fieldwork on the onshore margins of the Black Sea and one dealt mainly with new geophysical and modelling studies of the Black Sea basin itself. The former cover, in part, all segments of the Black Sea margin – Bulgaria (Balkans), Romania (Dobrogea), Ukraine (Crimea), Russia (Northwest Greater Caucasus), Georgia (Transcaucasia and Lesser Caucasus), and Turkey (Pontides). These are the projects led by: (1) F. Bergerat (CNRS, Paris), aimed at the determination of paleostress states associated with the main tectonic phases in the Balkan area during Meso-Cenozoic times, especially the so-called Cimmerian phases that occurred during the Triassic and Jurassic; (2) A. Saintot (VU, Amsterdam, moving to NGU, Trondheim), broadly focused on unravelling the early Mesozoic geodynamics – basin development and inversion – of the southern margin of the East European Platform as a whole and, accordingly, comprising structural geological fieldwork as well as magmatic, sedimentological, and paleomagnetic studies of mainly Triassic and Jurassic rocks in the Dobrogean and Crimean orogens and in the Greater Caucasus sedimentary basins; (3) M. Sébrier (CNRS, Paris), aimed at characterising Mesozoic and Palaeogene extensional deformation in the intermontane sedimentary basins of the Transcaucasus Depression-Lesser Caucasus area and relating this to regional crustal reconfigurations and oceanic basin development in the Black Sea, as well as to the kinematic evolution of the Caucasus collision; and (4) J.-C. Hippolyte (CNRS, Chambery), who studied the structural architecture of the Cretaceous syn-rift sedimentary sequence of the Black Sea basin revealed on its inverted southern continental margin in the Eastern and Western Pontides as well as younger tectonic events related to collision in the Pontides and their subsequent evolution. (5) The fifth project included in the Working Group is led by R. Stephenson (VU, Amsterdam) and comprised re-correlation of subsurface (seismic and well data) and geophysical data (gravity and magnetics) on the north-western margin of the Black Sea as well as the development of new velocity models of the crustal structure of the Black Sea from deep seismic and gravity data and tectonic subsidence modelling of the Odessa Shelf and Azov Sea areas.

In terms of the integration of the results of the component projects and their synthesis, the Working Group has identified four main themes for attention and elucidation, involving four broad periods of distinct tectonic evolution of the Black Sea area. These are:

(1) Mid-Eocene and younger shortening that is widespread, affecting almost all of the study area, in particular the northern and southern margins of the Black Sea and the orogenic belts west and east of the Black Sea. The onset of this deformation – and discrete pulses of compression thereafter – appears to be almost synchronous throughout the area although the question of timing needs more detailed investigation. In particular the tectonic style of the eastern Black Sea Basin could be anomalous, based on contemporaneous extensional tectonics onshore (in Georgia). This may represent the penultimate regime of extension in what was otherwise a broad zone of convergence throughout the Mesozoic and Cenozoic. Accordingly, it may provide important inferences on the geometry of indentation of convergence during the Palaeogene. Another fundamental issue has to do with the loci of deformation. Deformation is focused in continental crust (intense on the margins of the Black Sea, for example, but absent in its oceanic basinal part) suggesting that structural inheritance and strength play important roles in controlling intraplate shortening during the Cenozoic.

(2) Cretaceous extensional tectonics, being the main phase of development of the Black Sea basin, and its relationship with earlier extensional events in the Jurassic (and earlier). The Black Sea is generally interpreted as a back-arc basin but, in fact, fundamental issues such as the presence or absence of a related magmatic arc and the orientation of the related subduction zone remain vague at best. There are obvious implications for the geometry of extension and rifting within the western and eastern Black Sea basins and the role of broader plate configuration and kinematics in controlling this. It is possible, for example, that the Odessa Shelf-western Black Sea...
continent-ocean boundary is a transform margin rather than a rifted one as is commonly assumed.

(3) The significance of Cimmerian “Orogeny” tectonics throughout the study area, as expressed by the widespread occurrence of various Late Triassic-Jurassic aged unconformities. Of these, the “mid-Cimmerian” unconformity is the most profound but, otherwise, it appears as though Cimmerian tectonics are unlikely to be related to continental collision, rather being a response to (minor?) plate geometry reorganisations and/or to subduction-accretion “anomalies” broadly affecting the kinematics of convergence. An important element in understanding the Cimmerian phase of tectonics is the Crimean “Orogeny”, which is neo-Cimmerian (Late Jurassic, even possibly Early Cretaceous) in age and for which there is no evidence of ocean basin closure as is typically shown in existing plate reconstructions of the area.

(4) The important role of pre-Cimmerian tectonics in controlling all of the subsequent deformational history of the Black Sea area. There is considerable uncertainty regarding the geometry and evolution of the southern margin of Europe generally during the Palaeozoic and early Mesozoic. It appears as though there was no Late Palaeozoic accretionary event (i.e., “Scythian Orogeny”), adding to the European continent, but that widespread extensional tectonics of older crustal basement also prevailed throughout much of the study area during this time. Allied to this are issues such as the crustal affinity of the mid-Black Sea ridge and the nature of the basement of the Crimean Orogeny and the relationship of these, for example, with the crust of the Transcaucasus area. A fundamental question of great relevance, but one that is difficult to address in the context of the MEBE projects contributing to the Working Group, is the polarity of Paleo-Tethys subduction in the development of the Pontides Orogen in northern Turkey.

The Black Sea Working Group plans to address these issues in part in a Special Issue of an international journal. Besides this, the Working Group intends to prepare an overview chapter for a MEBE GeoArabia (tectonics/structural geology/modelling) volume. It will include a synthesis of all results of the component MEBE projects including newly prepared maps of tectonic data for appropriate times (main tectonic events, as discussed above). The paleotectonic maps will present revised paleogeographic reconstructions, implying a new model for the geodynamic evolution of the Black Sea area from the MEBE Programme synthesis.

CAUCASUS
Marc Sosson (CNRS-UMR Géosciences Azur, Sophia-Antipolis)

The MEBE fieldwork initiated through the Arabian-Eurasian collision zone from Eastern Anatolia to the Great Caucasus allowed the acquisition of new stratigraphic, structural, petrological, and geochronological data that provide good constraint on a North South transect for elucidating the basins and geodynamic evolution of this part of the Tethyan belt since the Jurassic.


Bitlis Metamorphic complex
The Bitlis metamorphic complex (30 km wide and 500 km long) rests directly on top of Cretaceous rocks that are related to the ophiolitic suture between Arabia and Eurasia. The Eastern Bitlis massif therefore must be considered as a nappe complex that strongly deformed rocks of the Arabian platform. Since the metasedimentary sequence of the eastern Bitlis complex contains low-grade HP-LT metamorphic minerals it is obvious that...
they were involved in a subduction-related setting very similar to that of western Anatolia. Lithological considerations of Proterozoic to Late Cretaceous aged successions suggest that the Bitlis nappe complex could be related to the South Armenian block to the north, but this requires further study.

**Lesser Caucasus Suture zone**
The South Armenian block is characterized by a Proterozoic basement and a Late Devonian to Lower Cretaceous sedimentary cover characteristic of a platform-type environment. Ophiolites were obducted over the South Armenian Block during the Late Cretaceous (Fig. 1). These (Sevan-Akera, Vedi, and Stepanavan ophiolites) correspond to an oceanic lithosphere probably formed with a slow rate of extension. Moreover, an andesite volcanic arc overlying oceanic crust can also be observed (Stepanavan, Vedi areas).

The outcropping rocks of the Eurasian margin in the Lesser Caucasus suggests magmatic arc activity occurring from Late Jurassic to Early Cretaceous times.

Collision between the South Armenian block and Eurasia occurred during the Eocene and produced folding of ophiolites, the magmatic arc, and the unconformable overlying Late Cretaceous basin. A possible extensional stage occurred synchronous with the late Eocene magmatic arc activity on both the South Armenia Block and the Eurasian plate. During Late Eocene to Miocene times, the Lesser Caucasus underwent NE-SW shortening, NW-SE folding and thrusting along the suture zone, with shortening propagating to the SW external part of the belt (between Kafan and Kajaran, Vedi area).

**Great Caucasus**

To the west, the tectono-stratigraphic evolution of the Greater Caucasus (Russia) in early Mesozoic times was different than that of Crimea-Dobrogea region. Several unconformities are observed in the western Greater Caucasus that constrain the tectonic evolution of the area. A rifting phase occurred during the Jurassic and sedimentary basins entered a post-rift subsidence phase in Late Jurassic times. The western part of the Greater Caucasus corresponds during the Jurassic to the western margin of the rift basin with shallow water sedimentation and sub-aerial extrusion of lava flows. The geochemical nature of Bajocian lavas suggests that a subduction zone was located to the south and that the Greater Caucasus basin was in a back-arc position. Basin inversion occurred in the Late Eocene. Normal faults that developed prior to folding are also widespread in the western part of Greater Caucasus and their inversion gave an extension affecting rocks up to Late Paleocene-Early Eocene in age. This event could be the far field effect of the rifting of the Eastern Black Sea basin - or of an Eocene reactivation of an older rift system.

The central part of the belt, with the highest elevation (and the highest rate of Neogene to present uplift compared to the western and eastern part of the Greater Caucasus), corresponds in the past to the thinner part of the Greater Caucasus rifted lithosphere: the present-day high elevation could be due to the subduction of this highly thinned lithosphere.

Key outcrops were visited in the eastern Great Caucasus, including the central part, its termination with the Caspian Sea, and the northern and southern fold-and-thrust fronts. The main objective of the fieldwork was to study large- and small-scale tectonic structures with an emphasis on the measurement of fault surface orientations, along with striation lineations, in order to obtain information on paleostress. The most predominant of the fault sets has a NNE-SSW direction with left- or right-lateral displacement. There is a whole range features from large-scale, fault-related folds to small scale folds, ramp folds, imbricates etc. The different structures pertain to a series of large tectonic zones that subdivide the mountain range. The main structural style is one of a fold and thrust belt. In addition, analysis of sedimentological data reveals a complete traverse of a passive margin rift margin type situation, with sediments from the lagoon to the reef, and out into the slope and distal basin (N to S). The rocks include limestone, turbidites (siliciclastic and carbonate), conglomerates, olistolithes, marls and shale. The presence of numerous sedimentary angular unconformities of different ages was confirmed.
The South Caspian Basin (SCB) is among the deepest basins in the world. It is still poorly understood in terms of the mechanisms that controlled its evolution as well as its geometry, timing of origin, and evolution. Because of the thickness of Late Cenozoic sediments, its offshore part cannot be considered in isolation for understanding its complex pre-collapse evolution, especially during the Mesozoic. The age of the oldest sediments of the SCB is unknown, being inaccessible because of their great depth. To solve this problem, we investigated the surrounding areas, including the margins of the SCB in Iran and Azerbaijan. This led to new fieldwork campaigns on the former margins of the SCB that were inverted during the Cenozoic stages of the Arabia–Eurasia collision. They form the Alborz, Kopet Dagh, Binalud belts in northern Iran and the eastern termination of the Greater Caucasus. The eastern termination of the SCB and its relationship with other Iranian basins being unknown, studies were also carried out on the Central Iranian blocks where remnants of Mesozoic deep basins exist. Using structural and brittle tectonic analysis, we aim at characterising the major tectonic events (age, stress pattern, etc.) that occurred since the Mesozoic on these margins. New field data on regional tectonic/sedimentary setting is combined with subsidence analysis inferred from field and/or offshore exploration data and numerical modelling is performed on offshore data.

The objectives of the South Caspian Working Group (SCWG) are to characterize tectonic events in terms of timing, regime, and orientation, as well as to present a new model of the geodynamic evolution of the greater South Caspian area including the Eastern Caucasus, Alborz, and Kopet Dagh, as well as structural relations with the Mesozoic basins of Central Iran such as in the Tabas and Nakhlak areas. The SCWG is integrating the results of 6 MEBE projects involving 9 European research institutes and universities (CNRS, UPMC, France; University of Würzburg, Germany; University of Milano-Bicocca, University of Milano, CNR-IDPA, University of Roma Tre, Italy; Fribourg University, Switzerland; Keele University, UK) and local organizations: Geological Survey of Iran, University of Tehran, Geology Institute of Azerbaijan, Azerbaijan State Oil Academy. The MEBE projects involved (and their leaders) are: “Lower Jurassic – Lower Cretaceous stratigraphy of the Alborz mountains” (F. Baudin, Paris); “Geodynamic evolution of Northern Iran in connection with the South Caspian Basin origin” (M.-F. Brunet, Paris); “Subsidence Mechanisms within the South Caspian Basin” (S. Egan, Keele); “The Permian and Triassic in the Elburz Range, Iran” (M. Gaetani, Milano); “Geodynamic evolution of the Yazd, Tabas and Lut blocks (Central Iran) by integration of palaeomagnetic, structural and stratigraphic data” (M. Mattei, Roma); “Tectonic evolution of the southern Talesh mountains (Western Alborz) and of the Gorgan region (Eastern Alborz); searching for the remnants of the Palaeotethys suture, Iran” (A. Zanchi, Milano). The Fig. 1 displays some of the activities of these projects.

Preliminary results show that an extensional phase occurred at the end of Triassic–Early Jurassic. It was following the Eo-Cimmerian tectonic phase induced by the collision of Cimmerian blocks with Eurasia. This event was associated with the deposition of the Shemshak Formation (Late Triassic to Middle Jurassic) in Alborz and Binalud as well as in Turkmenistan. We assign this extensional event to the rifting phase of the SCB. In the Mid-Jurassic an inversion is recorded in some places (Eastern Iran, North Alborz, North-Eastern Caucasus); it is interpreted either as a true compressional event or as the rift-drift “break-up” unconformity. The SCB probably opened in Middle–Late Jurassic leading to oceanic crust accretion. Several compressional tectonic events punctuated the post-rift period of thermal subsidence, especially at the Jurassic–Cretaceous boundary and in the uppermost Cretaceous. These compressional phases are evidenced by regional unconformities and deposition of clastic sediments. In the Eocene, a strong extensional event, associated with E-W trending normal faulting, led to the deposition of the thick volcanoclastic Karaj Formation in the southern part of the Alborz and the thick Talesh series (NW Iran and SE Azerbaijan). We assume that this regional sub-meridional extension is related to back-arc opening, behind the northward subducted Neo-Tethys oceanic lithosphere beneath the Eurasian margin. The next major orogenic period developed during the Late Cenozoic in connection with the beginning of Arabia–Eurasia collision. The thickest series in the SCB is represented by the Pliocene–Quaternary with more than 10 km of sediments deposited in a very short time interval (less than 5 Myr). This occurred within a framework of intense shortening. The erosion of orogenic belts surrounding the SCB (Caucasus, Talesh, Alborz, Kopet Dagh) provided a huge source of sediments, filling up the subsiding SCB as well as the foreland basins of the orogenic belts themselves.

The products of the SCWG will include: structural cross-sections of the Eastern Caucasus, Alborz and Kopet Dagh, and detailed lithostratigraphic columns in Permian, Triassic and Jurassic series of Alborz and Central Iran, numerical models of the offshore SCB, a tectonic calendar, and a geodynamic reconstruction of the area. The data provided by the SCWG will be integrated using a Geographical Information System (GIS). The GIS database will include geological outcrop data (photographs, sketches, structural measurements, etc), base map data, topography DEM, satellite imagery, regional geological cross-sections, and offshore depth maps.
The purpose of this project is to carry out a sedimentological, tectonic and sequence stratigraphic study of the Iranian part of the Tethys margin in order to constrain better the effects of tectonic and climate changes on the geometry of this margin. The Working Group includes the Angelier team working on the Mesozoic tectonic history of Zagros, the Razin team working on the Cenozoic stratigraphic history of Zagros and Robin’s team working on the Mesozoic stratigraphic history of the south Tethyan Arabian margin.

**Mesozoic history**

Three tectonic units have been studied, located along the Crush zone, from NW to SE: the Kermanshah, Saran-Aligurdayaz, and the Neyriz / Pichakun areas. A complete stratigraphic section is very difficult to establish in the Kermanshah area, because of intense folding. In fact, it is a stack of thrusted units. The area of Daran - Aligurdayaz was studied in 2003. Biostratigraphic data are in progress and will be available in 2006. During 2004 attention was focused mainly on a study of the Pichakun nappes. Five different thrusted units have been studied, from proximal to distal deep-sea deposits. The major advance in our knowledge included datings, that modify previous interpretations of the area and, second, the sedimentology and the sequence stratigraphy.

Four main lithostratigraphic units were defined. They are several tens of metres to a few hundreds of meters thick mappable units. They correspond to formations. Names have to be assigned according to the international stratigraphy.
graphic nomenclature, after discussion with colleagues from the Iran Geological Survey. Biostratigraphic data are based only on radiolarians (studied by S. Gorican). From base to top:

- **A Fm:** alternation of claystones–dominated intervals with massive clastic limestones (sands to conglomerates) units – maximum thickness 350 m. (lowermost Middle Jurassic - Oxfordian).

- **B Fm:** claystones with some intervals of silicified muddy or finered clastic limestones with radiolarites - thickness between 30 and 130 m. (Kimmeridgian - Berriasian-Valanginian).

- **C Fm:** alternation of fine-grained dominated heterolithics with coarse-grained himolithics. (Early Cretaceous).

- **D Fm:** This formation is composed of a lower member, made up of large conglomerates with blocks reaching a size of few hundreds metres (carbonate platform deposits), and of an upper member, composed of clays, cherts and clastic limestones (Aptian - Turonian).

All the facies are carbonate gravity flow deposits. They can be described using Mutti’s nomenclature of turbiditic facies, going to very coarse debris flows (clasts up to one hundred metres) and slumps to low density turbidity currents (radiolarites). No true channels have been identified while thick coarse-grained conglomerates exist (Middle Jurassic). This suggests a low efficiency of transport for this turbiditic system where all the deposits are stacked as lobes on the toe of the slope.

Two cycles of around 20-70 My duration can be defined; the first one has a backstepping hemicycle from the Middle Jurassic to the Kimmeridgian (A Fm and part of the B Fm) and a forestepping hemicycle from the Kimmeridgian to the Albian (part of the B Fm, C Fm, D Fm – lower Member); the second one is of Albian to at least Turonian age, with an unknown age for the backstepping / forestipering turnaround surface.

These cycles can be controlled by three factors: tectonic, eustasy, and the sedimentary flux (here the carbonate input). Knowledge of the carbonate flux presupposes knowledge of the geometry of the platform (in progress). Eustasy can be discussed using the Haq et al. (1987) sea-level curve (biostratigraphically recalibrated by Hardenbol et al., 1998) as a reference. For the whole time interval considered, sea level is rising and the end Kimmeridgian corresponds to a long term (10-50 My) sea level high. This can explain the Middle Jurassic–Kimmeridgian backstepping hemicycle but not the Kimmeridgian–Albian forestipping one. The latter could be, for its Early Cretaceous part, due to an increase in sediment supply. The lack of hiatus, truncations, shifts could suggest low local tectonic control before the Aptian-Albian, when a major tectonic event with destabilization of the platform occurred.

A similar study has been carried out on the Tethyan paleomargin of Oman for 6 years. In terms of data, the main difference is the higher number of outcropping tectonic units that allow a much better reconstruction of the paleomargin than in Iran. In Oman, all sedimentary environ-

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**Fig. 1 - Stratigraphic comparison of Iranian and Omanian South Tethyan margin.**

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**Cenozoic history**

The purpose of this project is a biostratigraphic and sequence stratigraphic analysis of the latest Cretaceous to Paleogene sequences of the Zagros mountains, mainly in the Lurestan area. The aims of the study are (1) to improve the biozonalations of benthic and pelagic foraminifera applied in this area, (2) to define a sequence stratigraphic model for the Late Cretaceous – Paleogene basins, (3) to characterize the geodynamic context and the main stages of the tectono-sedimentary evolution of this domain, and (4) to propose stratigraphical correlations and a structural comparison with the post-obduc-
An integrated approach, including biostratigraphy, sedimentology, sequence stratigraphy and structural geology will be used for this project. The expected results are an accurate biostratigraphical chart for the Paleogene foraminifera in this part of Iran, a new and detailed stratigraphical organization of the Late Cretaceous to Paleogene sequence in this domain, and a better understanding of the post-obduction evolution of the SE margin of the Arabian plate from the Oman to Zagros mountain belts. Our preliminary results give rise to new hypotheses about the Cenozoic Zagros basin evolution. These hypotheses are to be tested and improved by additional field work.

CENOZOIC KINEMATICS OF ZAGROS AND MAKRAN IN IRAN

Pascale Leturmy (UCP, Cergy-Pontoise)

The NW-SE trending Zagros is a fold and thrust belt resulting from the collision between the Arabian and Eurasian plates. It is composed of two arcs (Lurestan and Fars Arc) separated by a re-entrant, the so-called Dezful Embayment. Further southeast, the Makran is an emerged accretionary prism related to subduction of the Indian Ocean.

The work done in the Fars Arc

A complete balanced cross-section (Fig. 1c) across the south-eastern Zagros fold-thrust belt (ZFTB) has been performed during the two years of the MEBE project (Molinaro et al., in press). The main structural features that emerged from this section are: (1) In the south of the ZFTB, the Proterozoic-to-Recent sedimentary sequence has been decoupled from its Pan-African basement along ductile basal evaporites and folded into a series of large detachment anticlines. Ongoing shortening of these structures has resulted in migration of the basal salt layers into the cores of anticlines and propaga-

Fig. 1 - Incremental three step scenario through the southeastern Fars Arc (location: section 2 on Fig. 2).

Fig. 2 – A highly schematic organization of the basin based on stratigraphic data collected in the whole studied sections. This organisation reveals three main tectono-sedimentary cycles related to three main stages of the basin evolution. Each of these T.S. cycles corresponds to deepening – shallowing up facies succession interpreted as controlled by successive flexuration and uplift processes (foredeep – foreland stages).
tion of forelimb thrusts. (2) In the north of the ZFTB, deep-seated ramps have folded the hanging-wall rocks and produced imbrications and duplex structures within the higher levels of the sedimentary sequence. (3) Out-of-sequence thrusts, linked to major seismogenic basement faults, have cut through the structures in the cover of the ZFTB.

A three-step incremental restoration (Fig. 1a to 1c) of the section shows that two main phases of deformation can be distinguished in the tectonic evolution of the ZFTB: a Mio-Pliocene thin-skinned phase, during which most of the structures in the cover were generated, followed by a Pliocene to Recent thick-skinned phase – expressed as out-of-sequence faulting in the cover – which is currently marked by seismicity within the basement. In plan view, the initial structures of the south-eastern ZFTB developed with a curved shape essentially controlled by the shape and thickness of the underlying Proterozoic salt basin (i.e. the “Jura style”). In the subsequent basement-involved phase, out-of-sequence thrusts cut at oblique angles through the pre-existing structures of the cover. The total shortening absorbed in the cover amounts to at least 45 km, corresponding to ~22%.

This cross-section has been combined with a lithospheric section based upon the combined interpretation of gravity, geoid, and topography data sets. It highlights a previously undocumented lithospheric thinning beneath the Zagros collisional belt (Iran), which we propose is related to recent slab break-off at the continent-ocean plate boundary (Moho). This cross-section has been combined with a lithospheric section based upon the combined interpretation of gravity, geoid, and topography data sets. It highlights a previously undocumented lithospheric thinning beneath the Zagros collisional belt (Iran), which we propose is related to recent slab break-off at the continent-ocean plate boundary (Moho).

**Final products of the Group**

The aim of this working group is to produce cross-sections across the Zagros and Makran, and to propose a unified model of the kinematic evolution of the area during Cenozoic times.

The final products will be a series of six balanced cross-sections with kinematics, a map of basement faults involved in Cenozoic shortening and a discussion of several points described below.

The collision is believed to have propagated from NW to SE, so a series of parallel cross-sections would give an image of different stages of collision and of the transition between collision and subduction. From southeast to northwest we will propose a synthesis based on a serie of six cross sections (Fig. 2), some of which already exist, while the rest will be completed by the working group. The objective is to correlate those cross-sections and to discuss kinematics, timing of deformation, and the influence of pre-existing structures on the kinematic and deformation style along each section.

**The kinematic scenario** proposed above (Molinaro et al., in press) will be verified along the five sections crossing the Zagros and adapted, if necessary, to take into account the specific features of each. Nevertheless, the same scenario involving a thin-skinned tectonic phase followed by a thick-skinned tectonic phase is invoked in Central Zagros along cross-sections 4 and 5 (Sherkati et al., submitted). A kinematic scenario of the development of the Makran Arc coeval with the development of Zagros has yet to be proposed.

**Agenda of Cenozoic-Quaternary deformation** in Zagros is poorly constrained because of the lack of chronological data in the syn-tectonic sediments (Agha Jari and Bakhtyari). Based on a magnetostratigraphic study, Homke et al. (2004) proposed that deformation along the Main Frontal Fault began around 8.1–7.2 Ma in the Lurestan Arc. Deformation that is believed to have propagated from the NW toward the SE should be younger in the Fars Arc. A magnetostratigraphic study of the syn-tectonic sediments further south is planned in order to compare the timing of deformation in both parts of Zagros, the rates of deformation deduced from the syn-tectonic ages, and the rate of lateral propagation of deformation along the thrust belt.

**The shortening rates** along the Zagros will be discussed in this synthesis, to reconcile present-day shortening rates determined from geodetic data (around 9 ±2 mm/yr, Vernant et al., 2003) with the long-term shortening rates calculated with the balanced cross section, which is in the order of 4-5 mm/yr, considering total shortening along the Eastern Fars Arc section and the timing proposed by Homke et al. (2004).

**The problem of structural inheritance** (Pan-African and Tethyan structural framework of the Arabian plate) will be discussed in the synthesis in order to constrain their influence on sedimentary deposits (in particular salt layers) and on the kinematic evolution of the fold-thrust belt during Neogene orogenesis. Associated with this discussion a map of the basement faults involved in Neogene deformation across Zagros will also be realised. It will be based on geomorphological evidence, on the balanced cross sections, and on existing literature.
The Levantine region forms the deformed western border of the Arabian platform. It is a relict of the southern passive margin of the southern Neo-Tethys and the onland continuation of the Eastern Mediterranean basin. This continental margin was deformed during the Cenozoic closure of Neo-Tethys. The Levant margin is a key area for understanding the Mesozoic evolution of the Neo-Tethyan and East Mediterranean domains and the interactions of the Arabian, African, and Eurasian plates during the Cenozoic. A fundamental aim for academic and oil prospecting purposes is to understand the detailed tectonic and sedimentary evolution of this part of the Arabian plate. This is the primary objective of the ‘Levant group’. We study the development and rejuvenation of the Mesozoic basins during the opening of the Eastern Mediterranean as well as the Cenozoic compressive and strike-slip movements associated with the closure of Neo-Tethys and development of the Dead Sea transform fault system.

The ‘Levant group’ includes a tectonic team (leader C. Homberg) and a stratigraphic team (leader S. Ferry) with common objectives. The members of the Levant group are French, Lebanese, and Syrian scientists of the University of Lyon 1 (S. Ferry and Y. Merran), the University of Pierre et Marie Curie (C. Homberg, P.-Y. Collin), the CNRS (E. Barrier), C. Müller (Free researcher), the Lebanese Universities of Beirut (M. Mroueh, W. Hamdan) and Tripoli (F. Higazi), and the Syrian Universities of Aleppo (A. Matar) and Lattakia (K. Al Abdallah).

During 2003 and 2004, most of our activity focused on the acquisition of field data. The goal of the tectonic group is to constrain the tectonic evolution of Lebanon and Syria during Mesozoic and Cenozoic times. We aim at determining (1) the timing and driving mechanism of successive tectonic events and (2) the regional distribution of associated deformation, including regional basin geometry and Cenozoic deformation patterns, with attention to the rejuvenation of older fabrics. Structural field studies were combined with mechanical analysis of faults. Timing arguments like unconformities, erosional gaps, syn-sedimentary faults and related structures were examined in order to date the main periods of tectonic activity. Meso-scale brittle structures (faults, tension gashes, stylolites) were observed to establish the stress field during each tectonic event. We also characterized the kinematics and offset amount of the large-scale faults, with attention to successive reactivations and we correlated these fault displacements with the tectonic phases. The objective of the stratigraphic group is to construct transects through the Levant margin in order to constrain the sequence stratigraphy and paleogeography of the Arabian plate during the Mesozoic. We chose key sections in the Jurassic and Cretaceous sequences and studied the sedimentological facies and sequence stratigraphy. Biostratigraphic markers were observed to identify sedimentological hiatuses and to date the sequence boundaries. The objectives are to define the paleoenvironments and morphology of the shelf and to establish the transgressive-regressive cycles during the Mesozoic in Lebanon.

Our results and the published data will be synthesized in thematic maps of the western margin of the Arabian plate for key periods and integrated in geodynamical and paleogeographical reconstructions of the Middle East and Eastern Mediterranean domain. These maps are maps of active large-scale faults, maps of stress trajectories, and paleogeographic maps. Tectonic logs and stratigraphic transects will also be constructed. Our work aims to (1) acquire stratigraphic and tectonic elements relevant for oil prospecting in the Middle East, (2) establish a plate-scale tectonic and stratigraphic model explaining the development of sedimentary basins in the western Arabian plate and their inversion, and (3) address broad issues like the driving mechanisms of sequence stratigraphy and the initiation and maturation of plate boundaries.
Stratigraphic research covered within the MEBE area is patchy, neither the whole column being investigated nor the whole area considered. Four major themes are developed:

- Permo-Jurassic evolution in the Alborz/Kopet Dagh and Central Iran.
- The Mesozoic sedimentary successions of the deep basins along the Arabian margin of the Neo-Tethys.
- The Jurassic and Cretaceous sequences on other margins of the Arabian plate in Yemen and Levant.
- The post-collisional Cainozoic basins of the Zagros.

**Permo-Jurassic evolution in the Alborz/Kopet Dagh and in Central Iran**

The first line of research has been developed through the projects of M. Gaetani on the Permo-Triassic of Alborz, the M. Balini and A. Nicora research in the Yazd and Tabas blocks of Central Iran, and the F.T. Fürsich- F. Cecca work in the Alborz.

The Permian sedimentary succession of the Central and Eastern Alborz is up to 1 km thick in the depocentre on the northern side of the Range, but it may be represented by only a few metres or tens of metres of sandstones to the south. Frequent emersions, especially to the south and to the east, are marked by lateritic soils. The Triassic is represented by the rather homogeneous dolostones and limestones of the Elikah Fm. The age of its top is critical. When the topmost part is not eroded, it contains Norian foraminiferal assemblages.

The Early Cimmerian orogeny deeply deformed the northernmost part of the Alborz, while to the south and to the east, the molassic deposits of the Shemshak Fm. cover the Elikah with a gentle unconformity, often not visible at the outcrop scale. Since the first deposits of the overlying Shemshak Fm. are still Norian in age, we have evidence that the main deformation occurred during the Norian itself.

The Upper Triassic-Middle Jurassic Shemshak Fm. of the Alborz is an up to 4 km thick coal-bearing siliciclastic unit, bounded at its base and top by tectonic unconformities (Early and Mid-Cimmerian). It can be subdivided into a basal coastal plain facies unit with volcanic and marine intercalations (Triassic), a fluvial-lacustrine facies unit with coals (?Triassic-Lower Jurassic), and a transgressive-regressive marine shelf unit (Toarcian-Aalenian) grading into a Bajocian delta. For the marine upper part, ammonite dating indicates a poor correlation of 3rd- and 2nd-order sequences with other sea-level charts, suggesting tectonic control of relative sea-level changes. Corg- rich black shales occur in the lower part of the formation. The Shemshak Fm. was deposited in an E/W-trending basin and its lower part represents a Cimmerian molasse. From the Toarcian, increasing subsidence rates suggest crustal extension terminated by the Mid-Cimmerian phase of uplift and erosion. Renewed extension in the Bajocian resulted in block rotation, rapid subsidence, and deposition of deep marine marls (Dalichai Formation).

Permian to Jurassic evolution in Central Iran is broadly similar to that of the Alborz, with obvious local differences like the marine carbonates of the Nayband Group in the Tabas Block. However, a very different succession is present in Nakhlah, already described in the literature, but sampled bed by bed during the MEBE work. The succession is up to 2.4 km thick, spans the interval Early Triassic - Carnian and is overlain by Cretaceous rocks with an angular unconformity (Fig. 2). It is like an alien succession in the homogeneous panorama of the Triassic of the Northern and Central-East Iran. It records the evolution of an active margin during Early and Middle Triassic. Paleomagnetic studies in progress should allow to confirm or not the solution of 135° anti-clockwise rotation, proposed by Soffel & Forster (1984).

**The Mesozoic sedimentary successions of the deep basins along the Arabian margin of the Tethys**

The purpose of the project lead by C. Robin (Rennes) is three-fold: stratigraphic, sedimentologic and sequence stratigraphy study of the Iranian part of the Tethys margin in order to better constrain the effects of tectonic and climate changes on the geometry of this margin. A similar study has been carried out by the group on the Tethys margin of Oman. A comparison between both areas is in progress. The major results are new dates (based on radiolarians) that modify previous interpretations of the Iranian margin and paleoenvironmental reconstructions.
in a deep-sea setting, namely:
- No Triassic sediments have been identified.
- A major discontinuity occurred during Aptian time, with dramatic resedimentation of a few tens to one hundred metres-thick carbonate platform blocks.

- Two deepest events are recorded in the deep-sea-plain, during the Kimmeridgian and during the Late Albian-Cenomanian.

**The Jurassic and Cretaceous sequences on other margins of the Arabian plate in Yemen and Levant**

Field work was performed in Yemen by the G. Pavia-M. Fazzuoli team and in the Levant by the S. Ferry-Y. Collin team. The different Mesozoic successions of south-eastern Yemen were sketched out with sufficient detail to allow further structural syntheses and to reconstruct the evolution of this part of the Arabian passive margin. Nevertheless, only in recent times was it possible to clarify the sequence of paleoenvironmental changes affecting the key-sector for the Jurassic of Southern Yemen: the Wadi Hajar outcrops on the western slope of the Mukalla High. The MEBE team operated on several Jurassic sections aiming to verify what happened on the supposed border between the Sayun Basin and the Fartaq High. The chronostratigraphic differences detected among the Upper Jurassic formations indicate a diverse structural evolution of two depocentres separated by the Mukalla High.

The Lebanese basin represents a part of the Syrian Palmyrids basin with anomalously high subsidence. We evidence major unconformity associated, for some of them, to valley fills, that could be cut from more than one erosional cycle.

On Lebanon, the Jurassic sedimentary succession is well exposed, and more or less complete, relatively undeformed and 500 m – 1000 m thick. The Jurassic succession extends from the lowermost part of the Early Jurassic to an unconformity at the Jurassic-Cretaceous boundary. The main objectives of the MEBE study are to establish a new sedimentary, stratigraphic and sequential framework. From Neocomian to Aptian time, sedimentation is limited to the actual coastal chain. A Peri-Tethyan gap has been evidenced that separates the first transgressive phase (Aptian in age) from the second, Albian to Turonian, which is more marked throughout the Arabian shield. A regional tectonic drowning occurred from the Coniacian to the Paleocene, marked by clay limestones with planktonic fauna. Four main phases of volcanism are recognized stratigraphically, three in the Lebanon range and
The aim of the Working Group is to construct 7 lithospheric-scale cross-sections around the Arabian plate and to describe their evolution from the Late Cretaceous to the Present. The tectonic scenario will take into account all available data sets: geometry of basins and metamorphic domains, kinematics, pressure-temperature estimates in metamorphic rocks, radiochronology, subsidence history, gravity, heat flow, seismology... The viability of the obtained cross-sections will be tested with the fully-coupled thermo-mechanical code PAROVOZ.

The deep parts of the profiles will be constrained by geophysical data and inversion techniques: topography, geoid, gravity field and heat flow will be used to delineate the base of the lithosphere and the Moho when no seismic data are available, and delay-time tomography will be used to constrain the long-term evolution of the profiles.

The scientific rationale is to compare cross-sections in different stages of evolution and derive a mechanism for mountain building and subduction. We have selected typical sections that show the complete evolution from Late Cretaceous obduction, to Eo-Oligocene collision and the Neogene post-orogenic extension. One additional section will describe rifting and oceanic spreading in the Gulf of Aden in order to discuss the causes of the separation of Arabia from Africa and the relations between extension and subduction-collision on either sides of the Arabian plate.

Section 1: This section crosses the Gulf of Aden, including conjugates margins and oceanic domain. The construction of the cross-section will use geological data acquired during MEBE as well as geophysical and marine geology data obtained during offshore cruises and onshore seismological experiments conducted by the Laboratoire de Tectonique, besides published geological and geophysical data. Numerical modelling on this section will investigate the respective roles of far-field extensional stresses and of the Afar mantle plume. The asymmetry of the northern and southern margin and the asymmetry of oceanic crust production is clearly shown by recently obtained geophysical data. The proposed evolution will take into account the interaction between the moving Arabian and African plates and the fixed mantle plume.

Section 2: From the Makran to the Oman mountains, this section shows almost undisturbed structures related
to the Late Cretaceous obduction in the south (Oman) and the still ongoing subduction in the north (Makran). The analysis of the kinematics of ductile and brittle deformation recorded in HP-LT metamorphic rocks below the Semail ophiolite, as well as their P-T-t evolution allows describing the sequence of events that led to their final exhumation to the surface. The internal geometry and kinematics of the subduction channel that was active during obduction will be described. The proposed kinematics will be tested by thermo-mechanical modelling. P-T paths extracted from the model will be compared to the observed ones to choose the best model.

Sections 3 and 4 cut across the Zagros and its internal zones as well as the border of the South Caspian Sea and the Alborz Range. Compared to section 2 we have here a more advanced stage of the ongoing collision between the Arabian margin and the Iranian block. Two sections have been chosen to take into account possible differences in the timing of collision and amount of shortening between northern and southern Zagros. The comparison between these sections and section 2 may bring important constraints for unravelling the mechanism of uplift of the Iranian plateau. An additional important difference is the absence of high pressure and low temperature metamorphic rocks in the Zagros internal zones except in the south near Kerman and in the north close to the Turkish border. This absence is an indication of a peculiar subduction regime compared to classical Alpine belts. The causes of lithospheric thinning below the Zagros and Iranian plateau will be studied and numerically tested. The observations made during the MEBE program show that the first collision between the Arabian margin and the Sanandaj-Sirjan zone occurred between 35 and 23 Ma. The kinematics of the collision can be described from the early stages to the propagation of the decollement in the external Zagros. The history of the active margin before obduction and collision is recorded in the tectonometamorphic evolution of the Sanandaj-Sirjan metasediments and intrusive calc-alkaline plutons.

Section 5 describes the Tethyan suture and collision zone in eastern Turkey and the connection with the Black Sea and the Caucasus. The discovery of unknown HP-LT metamorphic rock above the Bitlis suture during the MEBE field work by Oberhänsli et al. will be used to reconsider the tectonic evolution of this region. The amount of subduction of continental units in this region is thus much larger than previously thought. Correlations with the internal zones of northern Iran and with the Taurides will be used to describe the history of obduction and collision along this transect. The propagation of deformation towards the north will be constrained by field observations made in the Caucasus during the MEBE program.

Section 6 and 7 attack the problem of post-orogenic extension. Western Turkey and the Aegean domain recorded successively Late Cretaceous obduction, Eocene collision and a phase of post-orogenic extension in the back-arc region of the Hellenic subduction zone beginning in the Late Oligocene – Early Miocene. Our pre-MEBE experience in this region and our recent observations will be used to constrain the cross-section and its evolution. Along these two transects the large amount of available metamorphic and radiochronological data will allow a precise reconstruction of the evolution of the subduction zone from the Late Cretaceous to the Present. Using the information gathered on the obduction process and earlier collision along the more eastern transects we will obtain a new description of the history of this region. The Aegean domain is one of the key regions studying the dynamics of the subduction channel and the mechanisms of exhumation of blueschists and eclogites and we hope that the evolution we will propose will be used in the future as a type-model for these questions.

Fig. 2 - Preliminary lithospheric-scale sections showing the main features related to subduction, obduction and collision.
Currently developed using Microsoft Access and ArcGis, the MEBE database will be only available to our sponsors. The final product will run under ArcGis 9 and will display interactive maps of the whole MEBE area. The screen will show a base map on which specific marks will be plotted. The user will have to choose the type of the base map (topographical, geological ...) to select his interest area. The SRTM tins (30” and 3’) will be proposed. Geological maps at 1:1,000,000 at least and/or 1:200,000 scale when available will be on hand. Then user will choose the domain of data he wants to consult: either spatial data as tectonic features or factual data as cross-section, borehole, and outcrop. Accurate data will be plotted with specific marks related to scientific observations (tectonic, metamorphic, paleostress, stratigraphy, sedimentology ...). When user will click on a mark, the data will be displayed either as table or as pictures. For instance if he clicks on a cross-section, the draw of the cross-section will appear; on this one, stars will indicate specific detailed observations (description, biostratigraphical table, geochemical curves, picture of rock section, paleostress stereograms ...). User has to click on star to read or to see the related data.

The MEBE database will include the data collected and synthesized within the MEBE scientific project and working groups. Those data are interpreted data (cross-sections, curves, canvas, PT paths, biostratigraphical tables ...); those data are recorded as pictures (jpeg format). Other data are very detail data as paleostress ones; those data are recorded in specific tables. To facilitate the recording, some specific softwares are developed.

All that products: databases, softwares, ArcGis projects, base maps will be available at the end of the MEBE Programme.
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