Environmental Geomechanics

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List of Abbreviations

ACF	Auto-Correlation Function
AWCP	Acoustic Water Column Profilers
CBM	Coal Bed Methane
CFE	Comisión Federal de Electricidad
CRP	Conservation Reserve Program
DEM	Digital Elevation Model
DITF	Drilling-Induced Tensile Fracture
DNRA	Dissimilatory Nitrate Reduction to Ammonium
ECD	Electron Capture Detector
FEM	Finite Element Method
GAM	Generalized Additive Model
GAMM	Generalized Additive Mixed Model
GLM	Generalized Linear Model
GLMM	Generalized Linear Mixed Model
LOT	Leak-Off Tests
LPB	La Popa Basin
MC	Multilayered Crust
MIMS	Membrane Inlet Mass Spectrometry
NOR	Nitric Oxide Reduction
PAL	Passive Aquatic Listener
REV	Representative Elementary Volume
SDR	Seaward-Dipping Reflector
SRV	Stimulated Reservoir Volume
TEB	Trans-Eurasian Belt

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Preface

Environmental Geomechanics covers a range of topics that are of increasing importance in engineering practice: natural hazards, pollution, and environmental protection through good practice. Transport of contaminants and other substances may occur in the fluids, e.g. water, water vapour and air, filling the pores of geomaterials as happens in waste disposal problems or durability problems. Mass transport also takes place in reservoir engineering problems, where the fluids involved are oil, water, and gas. First chapter deals with "alive" tectonomagmatic processes, which are reflected in neotectonics, topography, geophysical fields, and the present-day magmatic activity. Geotectonic position and metallogeny of the greater Altai geological structures in the system of the Central-Asian mobile belt is proposed in second chapter. Third chapter presents an approach on geophysical modeling of the surroundings of La Popa Basin, Ne Mexico, with gravity and magnetic data. Fourth chapter provides a comprehensive geomechanical study to optimize stimulation for a fractured tight gas reservoir in the northwest Tarim Basin. In fifth chapter, an innovative analytical approach based on the distributed dislocation technique is developed to simulate the roughness induced opening of fractures in the presence of compressive and shear stresses as well as fluid pressure inside the fracture. This provides fundamental basis for computation of aperture distribution for all parts of the fracture which can then be used in the next step of modeling fluid flow inside the fracture as a function of time. It also allows formulation of change in aperture due to thermal stresses. The objective of sixth chapter was to investigate the exploitation-related processes through the analysis of geochemical and production data of 39 wells. The goal of seventh chapter is to show that the present-day tectonomagmatic activity within the TEB can be interpreted that a new ocean has begun to open here. Eighth chapter examines the changes in land use between 1947 and 2007 focusing on the possibility that commercial uses generate significant environmental benefits. In ninth chapter, it is recognized experimentally that the compressibility of warm and ice-rich frozen soil is remarkable under loading, which will cause a significant deformation and affect the stability of infrastructure constructed in cold region. In tenth chapter, we studied potential links between environmental factors, nitrous oxide (N2O) accumulation, and genetic indicators of nitrite and N2O reducing bacteria in 12 boreal lakes. In last chapter, we identify specific environmental parameters, including components of the ambient background sound that are predictive of ice seal presence in the Bering Sea.

Contents

Chapter 1

GEOLOGICAL-GEOMECHANICAL SIMULATION OF THE LATE CENOZOIC GEODYNAMICS IN THE ALPINE-MEDITERRANEAN MOBILE BELT

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INTRODUCTION

Alpine-Mediterranean Mobile Belt, which currently ongoing to develop, is one of the best sites for studying of geodynamic mechanisms for formation of such regions. In this case we are dealing with "alive" tectonomagmatic processes, which are reflected in neotectonics, topography, geophysical fields, and the present-day magmatic activity. Last circumstance allows independent control of petrological processes in the underlying mantle of the belt. Comparison of geological-geophysical data available with the results of mechanic and mathematic simulation allows us to establish the relationships of all these processes and the character of their manifestation on the Earth's surface. This is the purpose of our study.

GEOLOGY AND PETROLOGY OF ALPINE BELT

Alpine-Mediterranean Mobile Belt (Alpine Belt) represents the western part of the huge Alpine-Himalayan collision zone, which appeared in the late Cretaceous-early Paleogene after closure of the Tethys Ocean. The suture of this neotectonic zone is traced by chain of late Cenozoic andesite-latite volcanism, stretching across Eurasia from Mediterranean to the Indonesian Island Arc and back-arc seas of the Western Pacific as well as areas of continental rifting and areas of intraplate basaltic volcanism.

The most complicated structure of this belt is in its west, in the Alpine segment (Fig. 1), where there is a whole system of mountain ridges, andesite-latite volcanic arcs and back-arc basins with thinned crust of intermediate to oceanic-type (Alboran, Tyrrhenian, Aegean Sea, and Pannonian Basin) occurs. Despite the differences in the morphology of these structures, they have several common features: along their periphery volcanic arcs and fold-thrust belts which form arc-shaped mountain ridges are developed. Among their thrust slices are often observed deep-water sedimentary rocks of Tethys, ophiolitic complexes, and sometimes blocks of the lower crust and upper mantle. In general, the situation in many aspects is similar to that which takes place on the active margins of continents and oceans. Such structures are characterized mainly for the West Mediterranean, while for the Eastern Mediterranean, as well as for the Black and Caspian seas typical passive margin. For this reason, we divide the Alpine Belt into two segments: the eastern, or the Aegean-Caucasian, and western, or proper Alpine, which will be considered separately.

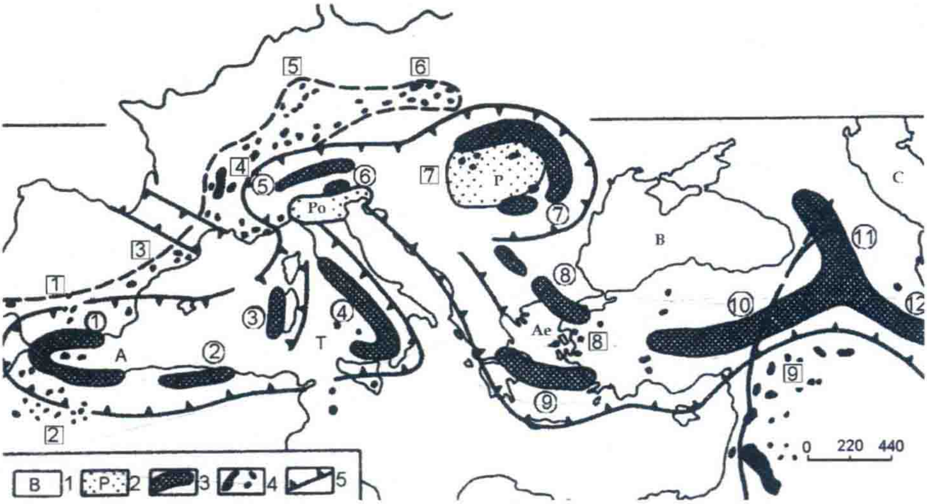

Figure 1. Development of the Late Cenozoic igneous rocks within the Alpine Belt1 – back-arc seas (A – Alboran, T – Tyrrhenian; Ae – Aegian) and "downfall" seas (B –Black, C – Caspian); 2 – back-arc sedimentary basins (P- Pannonian, Po – Po valley); 3 – Late Cenozoic andesite-latite volcanic arcs (in circles): 1 – Alboran, 2 – Cabil-Tell, 3 – Sardinian, 4 – South-Italian, 5 – Drava-Insubrian, 6 – Evganey, 7 – Carpatian, 8 – Balkanian, 9 – Aegian, 10-12 – Anatolia-Elbursian (10- Anatolia-Caucasian, 11 – zone of the Modern Caucasus volcanism, 12 – Caucasus-Elbursian); 4 – areas of flood basaltic volcanism (in square): 1 – South Spain and Portugal, 2 – Atlas, 3 – Eastern Spain, 4 – Central France massif, 5 – Rhine graben, 6 – Czech-Silesian, 7 – Pannonian, 8 – Western Turkey, 9 – northern Arabia; 5 – suture zones of major thrust structures interaction of a superplume head with mobile continental lithosphere. Good example of

such situation is the TEB (Sharkov, this book), where processes of collision continue now. The main feature of this belt is wide spread of the Late Cenozoic-derived volcanism, which has displayed practically coeval conditions on all its length, presuming existence of a superplume (or asthenospheric rise) beneath it. The belt has the most complicated structure within the Alpine segment, where a system of andesite-latite volcanic arcs and back-arc basin, bordering by nappe-folded mountain ridges were observed. In front of these ridges in Western Europe, north-west Africa and Arabia, coeval rift systems and flood basaltic volcanism often occur

Aegean-Caucasian Segment

Caucasian part of the segment is located to the north of the major suture zone traced by ophiolites of Cyprus, Syria, southeastern Turkey, Zagros, etc. (Periarabian ophiolitic arc). Late Cenozoic Anatolian-Elbursian andesite-latite volcanic arc is developed at its rear. It, in turn, is formed by two arcs – Anatolian-Caucasian and Caucasian-Elbursian, touching in the transverse (Transcaucasian) zone of the latest volcanism (Fig. 1). The Black and Caspian seas with oceanic crust, cut Pre-Pliocene structure of the Caucasus and the Kopet Dag; they are filled with Mesocenozoic sediments of 12-15 km thick. The nature of these deposits, until the late Miocene was generally similar to developed within the Caucasus and the Kopet Dag (Zonenshain, Le Pichon, 1986).

The Caucasus is located in the zone of the Arabian syntax (Burtman, 1989), where Arabian plate is subducted beneath Eurasian. Specific analog of deep-see trench is represented by the Mesopotamian trough here, which, beginning from the Eocene, is experiencing an active submergence, due to thick molasse accumulated (Ponikarov et al, 1969). The northern part of the Arabian plate began to rise above sea level in the late Oligocene and early Miocene, about 26-25 Ma when there began the development of basaltic volcanism (Sharkov, 2000) and the Red Sea rift opened up in southwest, separating Arabian plate from Africa. Rate of ascending movements sharply increased to the Miocene-Pliocene boundary, when Gulf of Aqaba opened approximately 5 Ma and Arabian plate began quickly shifted to the north along a large Levant Fault (Dead Sea transform) (Kopp, Leonov, 2000; Prilepin et al, 2001; Sharkov, this book). However, this displacement is hardly manifested in the Greater Caucasus shift and, moreover, GPS data indicate that the width of the central Caucasus is not decreasing but increasing (Shevchenko et al, 1999)

Specific structure occurred at the northern side of the Black Sea. Judging from the geological and geophysical data along the profile of Tuapse-Armavir, the Black Sea microplate is separated from the Eurasian by narrow subvertical zone of strong positive gravitational anomalies (Shempelev and et al, 2001). It concerned to large blocks of deformed and metamorphic rocks, close on the density to crust-mantle mixture. This zone can be traced to depth of 60-70 km and the Moho is not established here. The northern blocks move upward along their separating steeply-dipping faults, ensuring the existence of mountain relief of the Western Caucasus.

Formation of the Black Sea began, apparently, in the early Cretaceous, but significant deepening of the basin occurred at the Oligocene-Early Miocene boundary (Zonenshain, Le Pichon, 1986, Nikishin et al, 2001), followed in the Miocene by filling of the deep-water depressions by sediments and a gradual shallowing of the basin (Kazmin et al, 2000). Since the Pliocene-Quarternary new significant deepening of the Black Sea basin has occurred (Nikishin, Karataev, 2000), which occurred almost simultaneously with the uplift of the Caucasus and Crimea, which in the Oligocene-early Miocene were not expressed in the relief (Neotectonics…, 2000; Kostenko, Panina, 2001). The close sequence of events took place in the South Caspian Basin, which is a similar structure (Zonenshain, Le Pichon, 1986; Grachev, 2000).

Aegean part of the segment is characterized by island arc associated with subduction of the oceanic East-Mediterranean plate beneath the Eurasian (Papazachos et al., 1995). There are all typical structures of the active zones of transition from continent to ocean here: the deep-water Hellenic trough, Aegean volcanic arc and back-arc Aegean Sea with basaltic magmatism in its periphery (in the west of Asia Minor, near Izmir).

Numerous deformations of extension in subhorizontal submeridional direction (strike-slip and normal faults, nappe-thrusts, grabens, etc.) are known in the Aegean basin and in adjacent parts of Greece and Turkey (Prilepin et al, 2001). At that for Balkan Mountains in the north are characteristic north-vergentes imbricate nappes and thrusts whereas for Hellenides-Aegides-Taurides they are south-vergent. Judging from the seismic data, the stress state of the subhorizontal N-S stretching is characteristic of only for the upper 50-60 km of the Aegean basin lithosphere, leading to its expansion. At greater depths within the mantle beneath the basin both in south and north are fixed compression conditions. The regions of extension and compression are in direct contact by subhorizontal section at depth of 70-80 km; probably, it is the boundary of lithosphere and plastic material of extended plume head.

Aegean volcanic arc is a Pleistocene in age, but the development of the Aegean Sea, started earlier, about 12 Ma (Evsyukov, 1998). Apparently, earlier the main subduction zone located north, and its residues were survived in Dinarides and western Asia Minor (Western Anatolian: Fig. 1).

Descent of the Eastern Mediterranean (Ionian Sea, underwater Medina Ridge, Levant Basin) began in the late Miocene (Evsyukov, 1999).