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A R T Y K U Ł Y

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GENERAL TENDENCIES AND DIVERSITY ON RECENT GEODYNAMICS OF ALPINE OROGENIC SYSTEMS IN SOUTHERN EUROPE

INTRODUCTION

Orogenic areas have always drawn attention of geologists, geomorphologists and geophysicists, due to both high amplitudes of uplift during the neotectonic period and high energetic potential of recent morphogenetic processes. However, the recent endodynamics of geomorphic processes has hardly been considered. Except seismicity and volcanism, the global and regional biosphere programs focus mainly on the studies of exogenic processes. The Alpine orogen of Southern Europe has served for a long time as a test area for geotectonic, geomorphological and geodynamic studies of different type. Moreover, it is one of the best geodetically studied regions of the world, for which a set of regional and national maps of recent geodynamics has been published (Lilienberg 1969, 1980; Lilienberg and Mattskova 1970). All this makes it possible to describe some features and tendencies of recent movements.

GENERAL TENDENCIES

Recent GPS measurements have shown that the Alpine orogenic belt of Southern Europe is under transversal compression, as a result of plate collision. Horizontal motions play the leading role in endodynamics of morphostructural development, and vertical movements are derivatives of the horizontal ones. The rates of horizontal displacements are here between 3 and 7 cm/yr; those of vertical

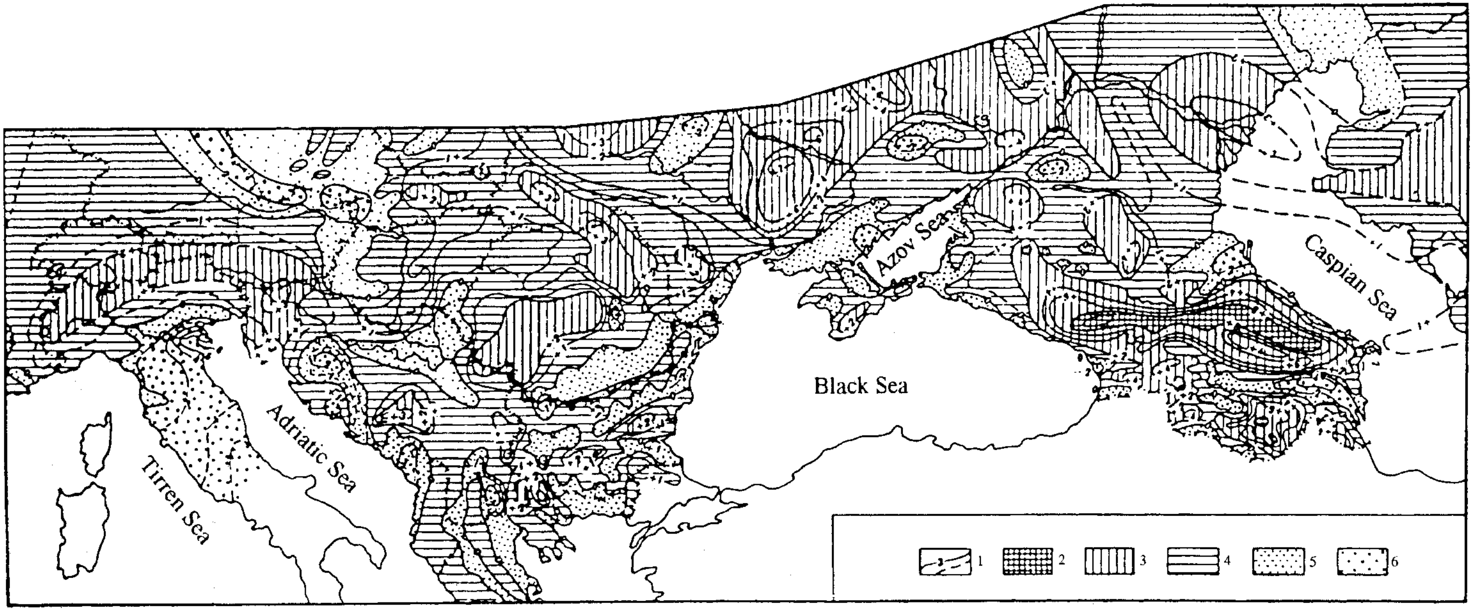

Fig. 1. Scheme of recent vertical movements of Alpine orogeny belt of the Southern Europe according to data of repeated levelling.
1 — isolines of movements in mm/yr; regions of prevailing rising: 2 — intensive, 3 — moderate, 4 — weak;
regions of prevailing subsidence: 5 — weak, 6 — moderate and intensive

Ryc. 1. Schemat współczesnych ruchów pionowych systemu alpejskiego Europy Południowej opracowany na podstawie powtarzanych niwelacji.
1— izolinie ruchów w mm/rok; regiony o przewadze podnoszenia: 2 — intensywnego, 3 — umiarkowanego, 4 — słabego;
regiony o przewadze wginania: 5 — słabego, 6 — umiarkowanego i intensywnego

motions being one order of magnitude smaller. Another regularity is the block-type character of morphostructures which is reflected in the pattern of recent vertical movements. Plicative deformations are of local character, only. Active fault zones are marked by high gradients of displacements (up to cm/yr/km) and produce a wide spectrum of kinematic forms. The dynamics of the complicated mosaic of morphostructures of different age and type is sometimes inherited from neotectonic, Pleistocene and Holocene epochs; more frequently, however, it is superimposed upon older structural pattern due to fairly recent morphogenetic processes (Lilienberg 1983, 1988, 1994). Repeated levelling surveys reveal that vertical movements change their sense, showing quasi-periodicity of 1, 2–3, 5–7, 10–15, 30–35, 50–60, 100–120 yrs, reflecting the dynamics of changeable lateral stresses in the Earth's crust and upper mantle. Hence, the spatial and temporal variations of recent movements are connected with both the discretness of the crustal structure and oscillatory character of geodynamic processes.

The pattern of recent vertical movements shows that the orogenic belt of Southern Europe reveals increasing intensity and contrast from the west to the east, i.e. from the Alps to Caucasus and the Caspian Sea (Fig. 1). Mutual relationships between geodynamics and morphostructural differentiation are of complicated character, showing different levels, types and rates in individual parts of the plate collision zones (Lilienberg 1983, 1985).

ALPINE MOUNTAIN SYSTEM

The area in question is characterized by moderate vertical movements of intensities similar to those of the "platform type" (Fig. 2; cf. also Fourniquet 1977; Jeanrichard 1975; Lilienberg 1983). According to the Austrian, Swiss and Italian levelling data, the inner zone of the Alps is subjected to uplift of 1–2 mm/yr and more (Fig. 2), whereas its eastern part displays rates up to 3–4 mm/yr, as shown by Yugoslavian geodetic data. Therefore, different patterns of mobility of individual nappes and suture zones, like that of Ivrea, can be singled out. The outer zone of the Alps shows smaller rates of uplift (up to 1 mm/yr); whereas the western termination of the Alps, influenced by geodynamics of the Ligurian depressions (Fourniquet 1977), is characterized by block-type pattern of movements: Avignon depression –0.7 to –1 mm/yr, Aix graben –0.4 to –0.8 mm/yr, Moure horst 0.4 to 0.7 mm/yr.

CARPATHIAN AND BALKAN MOUNTAIN SYSTEMS

This region is characterized by another style and level of geodynamic processes (Lilienberg 1968, 1969, 1983; Map 1973, 1979). Moderate vertical movements (3 to 5 mm/yr), showing some blok-type differentiation, are typical.

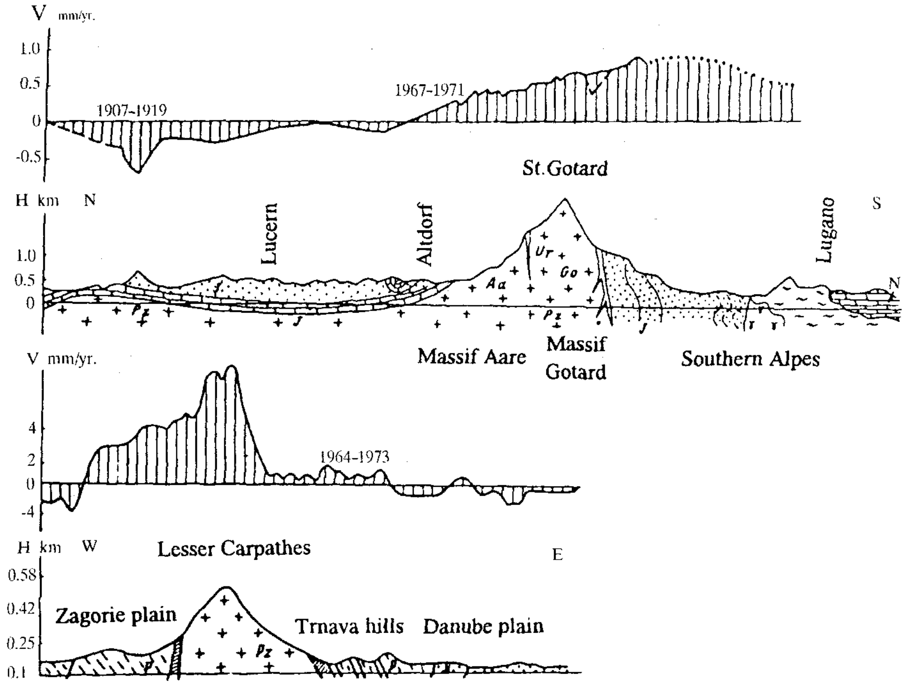

Fig. 2. Geological cross profile and vertical movements across Central Alpes and Lesser Carpathians (mm/yr)

Ryc. 2. Przekrój geologiczny oraz ruchy pionowe w Alpach Centralnych i Małych Karpatach (mm/rok)

The Western Carpathian domain is influenced by weak subsidence of the Upper Danube Depression (–1 to –2 mm/yr), the Outer (Polish) Carpathians show weak uplift (up to 1 mm/yr), the Central Carpathians are being moderately uplifted (up to 2 mm/yr), whereas the Eastern and Southern Carpathians are rapidly rising (3–5 mm/yr). The Fore-Carpathian and Trans-Carpathian basins display weak subsidence. Along the Olt river valley, where Vrancea earthquakes do occur, recent extension along faults is noted. It is remarkable that after the Vrancea 1977 earthquake, the uplift rates in the Eastern and Southern Carpathians increased sharply up to 8–10 mm/yr.

Repeated triangulation surveys in the Czech Republic, Slovakia and Ukraine point to horizontal shift of the Carpathians towards the north and north-east, proceeding at rates of 8 to 10 mm/yr (in the Lipnik test area even 15 mm/yr), reflecting recent thrusting onto the Carpathian Foredeep (Somov *et al.* 1983; Vyskočil 1984). The West Carpathians are moving away from the Bohemian Massif. Some structures (Magura Nappe, Vyhorlat-Hutin volcanic ridge, and others) are moving to the north; the rate of extension in the Pieniny Klippen Belt zone being c. 9 mm/yr. In the East Carpathians, the inner zone is being thrust upon the outer zone at a rate of 2.5 cm/yr, the right-lateral component of movement attaining 9 mm/yr. The rates of horizontal displacements obtained by classical geodetic methods are lower than those inferred from the GPS measurements (2–5 mm/yr).

The Upper Danube Depression subsides at a rate of 2–3 mm/yr, showing some minor block movements. For the Middle Danube Depression the alternation of weak subsidence (–0.5 mm/yr) and weak uplift (1 mm/yr) zones is typical. The same holds true for the Lower Danube Depression. The latitudinal sector of the Danube river coincides with a regional fault which subdivides the Moesian plate into two blocks: the subsiding Romanian depression (–1 mm/yr) and the rising North Bulgarian plate (1–1.5 mm/yr).

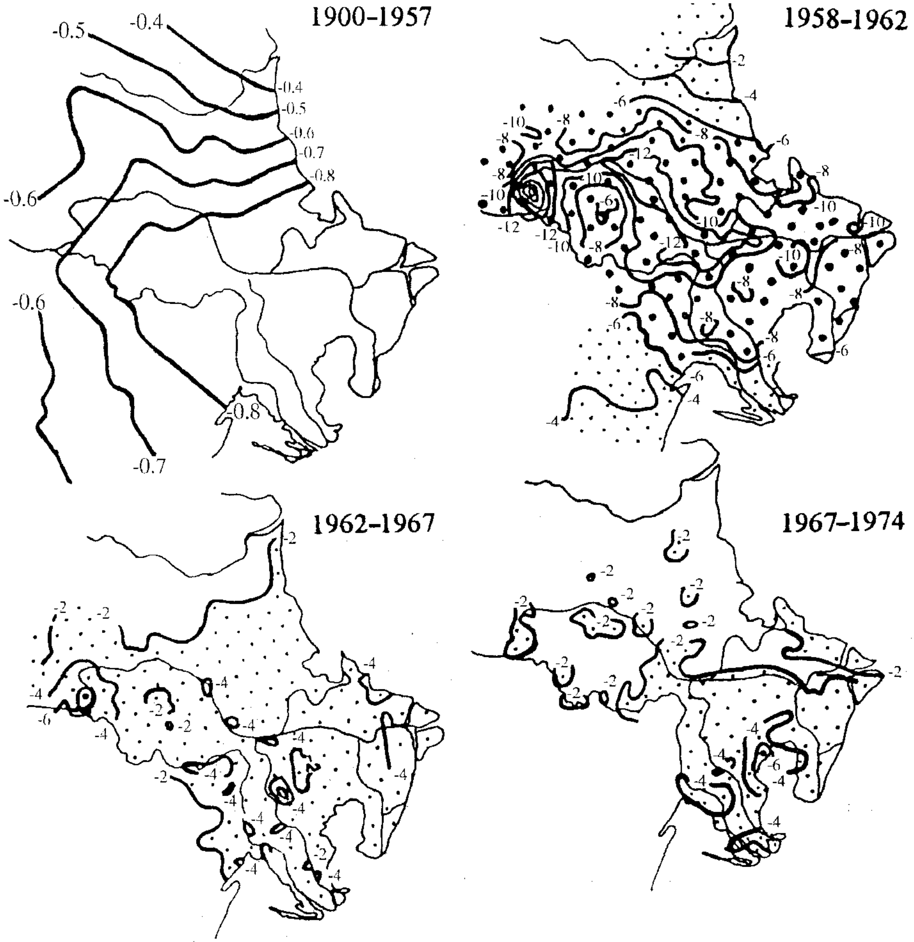

Fig. 3. Spatial and time variations of vertical movements of eastern portion of Po depression (North Italy) in mm/yr

Ryc. 3. Przestrzenne i czasowe zróżnicowanie ruchów pionowych we wschodniej części Niziny Padańskiej (północne Włochy) w mm/rok

The Dinarides show variable geodynamic regime. The horizontal push of the Adria microplate results in alternation of diagonally oriented zones of uplift (2–3 mm/yr) and subsidence (1–2 mm/yr; in the Shkoder depression even –5 mm/yr).

Repeated levelling in the 1963 Skopje earthquake epicentral zone revealed oscillatory and wave-like pattern of vertical movements (Lilienberg 1968, 1969, 1985). The levelling during the 1921–1956 yrs registered weakly differentiated movements (Fig. 7), whereas in the period of 1956–1964 the differentiation sharply increased, from –7 to +3 mm/yr. The most contrasting movements were observed in the Skopje depression, where the destroying earthquake did occur. In 1964–1967 the amplitudes of movements diminished, but the wave of contrasting motions was shifted eastwards to the Uroshevats depression. In 1967–1972, a new wave of contrasting movements appeared again on the west. Hence, a passage of waves of vertical movements from the west to the east can be inferred, including morphostructural blocks 100–120 km in diameter. Analogous spatial and temporal variations have been encountered in the eastern part of the Po Plain, Northern Italy (Fig. 3).

Generally speaking, the reconstruction of kinematics of vertical movements in the Balkan Peninsula is strongly connected with the activization of recent seismicity (Lilienberg 1983, 1985). Such an activization is also typical for the southern crystalline massifs (Serbo-Macedonian, Pelagonian, Pirin, Rodope; 5–6 mm/yr) which are surrounded by mobile depressions of the Adriatic and Aegean Seas.

CRIMEA MOUNTAINS

The suture structures of the Crimea Mountains were formed as a result of underthrusting of the Black Sea microplate under the Eurasian Plate, and at present are under compressional regime (Blagovolin *et al.* 1975; Lilienberg and Somov 1994). Repeated levelling in the Crimean test area shows secular tendencies to moderate uplift (> 3 mm/yr; Fig. 4). The northern and southern, lower-situated, parts of the Crimea Mountains show well-pronounced block differentiation. The increase or decrease in the intensity of uplift in this region can be interpreted (Fig. 5) as a result of pulsation mechanism, characterized by alternating compression/extension events (Lilienberg 1985; Lilienberg and Somov 1994).

Measurements of 1964–1969 revealed reactivation of relative uplift up to 5–7 mm/yr in the axial part of the mountains. Levellings conducted between 1969 and 1974 registered the inversion of this trend, i.e. subsidence up to 5–10 mm/yr; whereas in 1974–1977 another change of the sense of movements towards uplift took place. The principal longitudinal (Simferopol, Demerdzha) and transversal (Salgar, Yalta) faults are marked by high-gradient

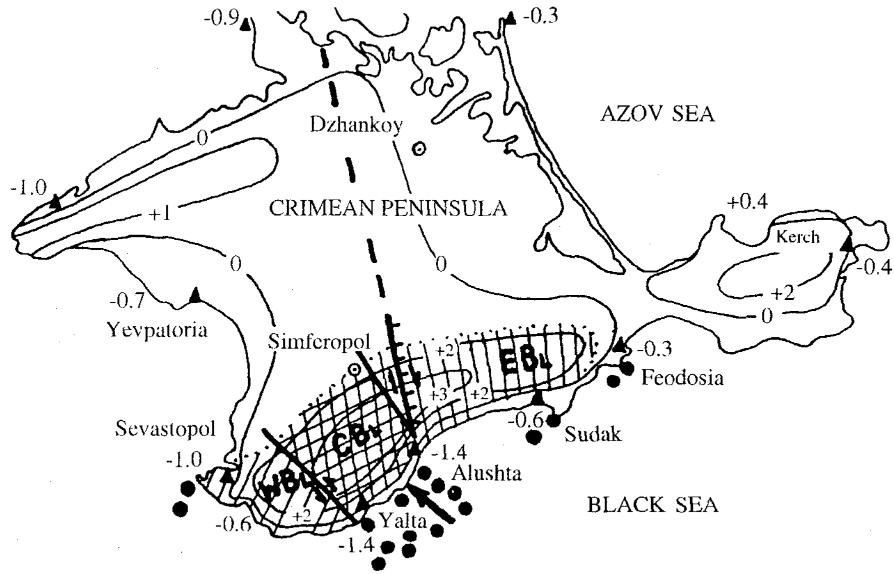

Fig. 4. Intensity and direction of recent tectonic movements in Crimea (explanation in the text)

Ryc. 4. Intensywność i kierunek współczesnych ruchów tektonicznych na Krymie (objaśnienie w tekście)

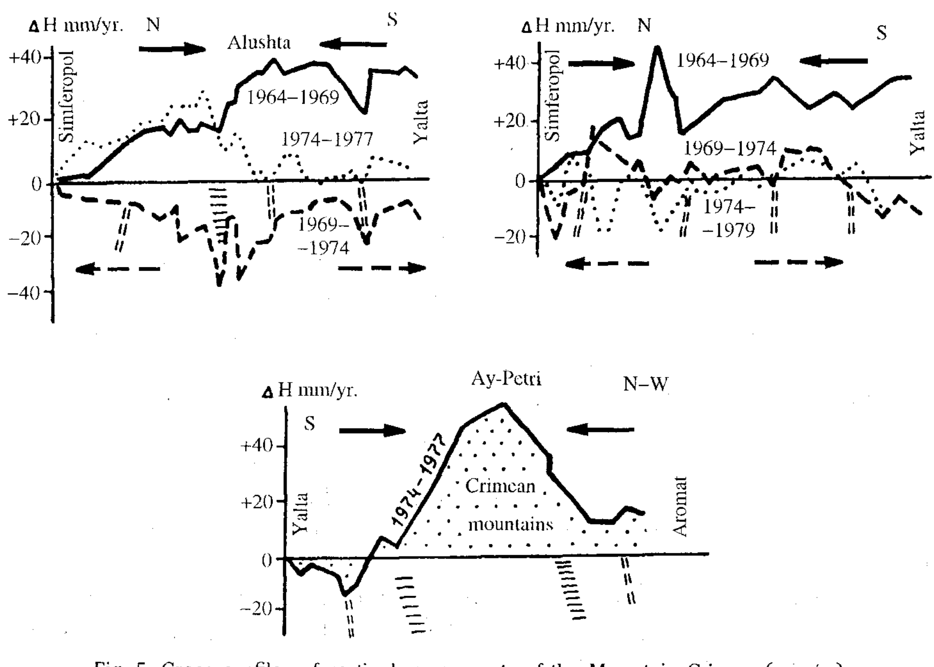

Fig. 5. Cross profiles of vertical movements of the Mountain Crimea (mm/yr)

Ryc. 5. Przekroje pokazujące pionowe ruchy w górach Krymu (mm/rok) zones and play the role of geodynamic hinges. The pulsation mechanism of alternating compression/extension events is manifested by long-term (tens of years) and short-term variations of the stress field. Following the increased seismicity in 1984 (255 earthquakes) at the end of this year, the relaxation of stresses responsible for relative extension was fixed by shortening of the sides of linear angle measurements in the micro-test area (Lilienberg and Somov 1994).

The plate interactions in Crimea are of very complicated character. The underplating resulted in a subdivision of the plate margins into a number of blocks which show both horizontal and vertical motions. Basing on GPS surveys conducted at Simeiz, the southern part of the Crimea mountains appears to be moving towards the NE at 2 m/yr. The central block of the orogen has been pulled out and uplifted, which is reflected in the right-lateral shift along the Salgir transversal fault (up to 3 m according to the results of two cycles of both linear and angular measurements), as well as in the left-lateral movement along the Yalta fault. Another result are lower rates of movements of the western and eastern blocks (up to 0.5 m/yr) and their splitting (Fig. 4). The displaced part of the adjacent shelf and continental slope, showing high concentration of seismic events, coincides with the central block. Long-base measurements registered as well general compression (underthrusting) along the Demerdzha longitudinal fault, on the southern slope of the Crimea mountains.

CAUCASUS AND TRANSCAUCASUS

Recent geodetic measurements supplied a wealth of new data on the mechanism and spatial and temporal variations of the recent geodynamics of the mountain systems of Greater and Lesser Caucasus and the Armenian Highland (Gerasimov and Lilienberg 1984; Lilienberg 1980, 1985, 1994; Lilienberg and Yashchenko 1991). This part of the Alpine orogenic belt is characterized by the highest intensity, differentiation and contrast of vertical movements (Figs 1, 6, 7). Their amplitudes attain 1–2 cm/yr, ranging from 1–1.5 to –1 cm/yr. The Greater and Lesser Caucasus show constant uplift up to 1–1.5 cm/yr, whereas the Armenian Highland and the Adzharo-Trialet system are being uplifted at rates of 1 cm/yr and 0.5 cm/yr, respectively. The Azov, Kuban, Terek, Sulak and Samur depressions in the Northern Caucasus reveal subsidence of 0.5 cm/yr, and the Rioni and Lower Kura intramontane depressions in the Transcaucasus are being lowered at –1 cm/yr. Differences in rates of vertical motions between the mountains and depressions attain 1–2 cm/yr.

A general feature of recent geodynamics of the area in question is the spatial regularity of vertical movements, showing strong correlation with the morphostructural subdivision. Within both the mountains and depressions, longitudinal morphostructural steps of differentiated elevation and longitudinal blocks, subdivided by high-gradient zones of active faults, can be distinguished. In the Greater Caucasus, the following transversal morphostructural blocks of different rates of uplift occur: Central Caucasus (1–1.5 cm/yr), Western Caucasus (up to 0.5 cm/yr), Eastern Caucasus (up to 1 cm/yr), as well as the northwestern (+0.2 – –0.1 mm/yr) and southeastern (4–6 mm/yr) periclines. A similar differentiation can be found among longitudinal morphostructural steps: the central crystalline massif (1–1.5 cm/yr), Northern Caucasus monocline (4–6 mm/yr), North Yura depression (0.4 mm/yr), Adzharian graben (7–8 mm/yr), Abkhaz massif (6 mm/yr), Amtkela ridge (5 mm/yr), and the North-Caucasus and Kolkhida depressions (1–3 mm/yr). The same regularity characterizes the Lesser Caucasus and Armenian Highland, alongside with the marginal and intramontane depressions (Lilienberg 1969, 1980, 1985; Lilienberg and Mattskova 1970; Lilienberg and Yashchenko 1991). The gradients of displacements across faults subdividing individual blocks change from 0.1 to 1.0 cm/yr. Displacements along the most active faults cause breaks of hydro-, oil- and gas pipelines, as well as of irrigation and road systems.

The spatial and temporal variations of both vertical and horizontal movements are another important feature. For a long time, geologists and tectonicians used to considered recent movements to have been inherited from neotectonic and Quaternary periods. Data collected in the Caucasus, Crimea and Balkans show that the sense of movements is changeable. Levelling surveys crossing the Greater and Lesser Caucasus have revealed two closely-spaced in time epochs of movements, showing different sense and subparallel orientation (Fig. 6). Measurements conducted in the 1925–48 and 1950–68 period showed that the Greater Caucasus was subjected to intensive block-type uplift of 1–1.5 cm/yr which, during the 1968–69 and 1973–75 time-span, was replaced by neutral movements or even subsidence of the order of –2 to –3 mm/yr. Such a trend can be explained by the replacement of transversal compression by transversal extension. Similar regularity has been found in the Crimea mountains and the Skopje region. Two epochs of contrasting sense of recent movements have been detected by repeated levelling across the Lesser Caucasus (Fig. 6): subsidence of –1 cm/yr during 1911–29 and 1940–53 was replaced by uplift of 1–1.5 cm/yr in 1940–53 and 1972–74 time-spans. One can conclude that the orogens of the Greater and Lesser Caucasus reveal out-of-phase displacements whereas the Transcaucasian depressions play the role of an hinge. The pulsation mechanism of alternating compression/extension is characterized by geodynamic waves of periods of 10–15 and 20–30 years (in the Crimea and Balkan region 5–7 years). Levelling transects located along the foothills of the Greater and Lesser Caucasus register geodynamic waves of sublongitudinal orientation (Fig. 7). In the Fore-Caucasus area, measurements conducted between 1914–30 and 1945–50 registered moderate differentiated movements which, in a period of 1945–50 and 1970–74, were replaced by block uplift, as a result of the change from extension to compression. The amplitudes of displacements attain 0.5–1 cm/yr (Lilienberg 1992, 1994). Levelling data collected in the Transcaucasian region in the periods of 1910–1914 and 1936–37 and 1949–50 and 1974–75

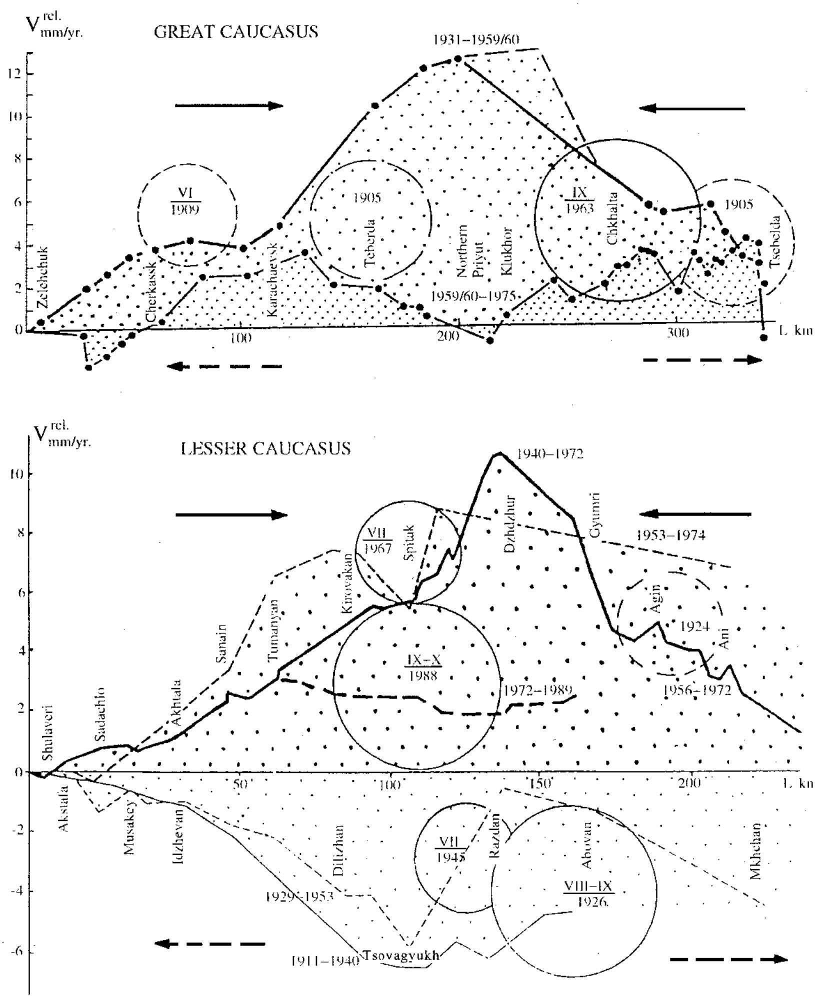

Fig. 6. Sublatitudinal oscillation and wave movements of different directions of the mountain systems of the Greater and Lesser Caucasus

Ryc. 6. Ruchy oscylacyjne i falowe o różnym znaku na profilu szerokościowym Wielkiego i Małego Kaukazu

reveal geodynamic waves passing from the west to the east, similarly to those in the Skopje and Balkan regions; the diameter of morphostructural blocks being, however, 300–400 km.

The superposition of both longitudinal and trasversal geodynamic waves creates a complicated stress field of the Caucasus area. Temporal changes of this field coincide with those of seismic activity, abnormal changes of the Caspian Sea level, as well as the manifestations of exogenic hazards (landslides, avalanches, glacier surges, mudflows, etc.; cf. Lilienberg 1989, 1994).

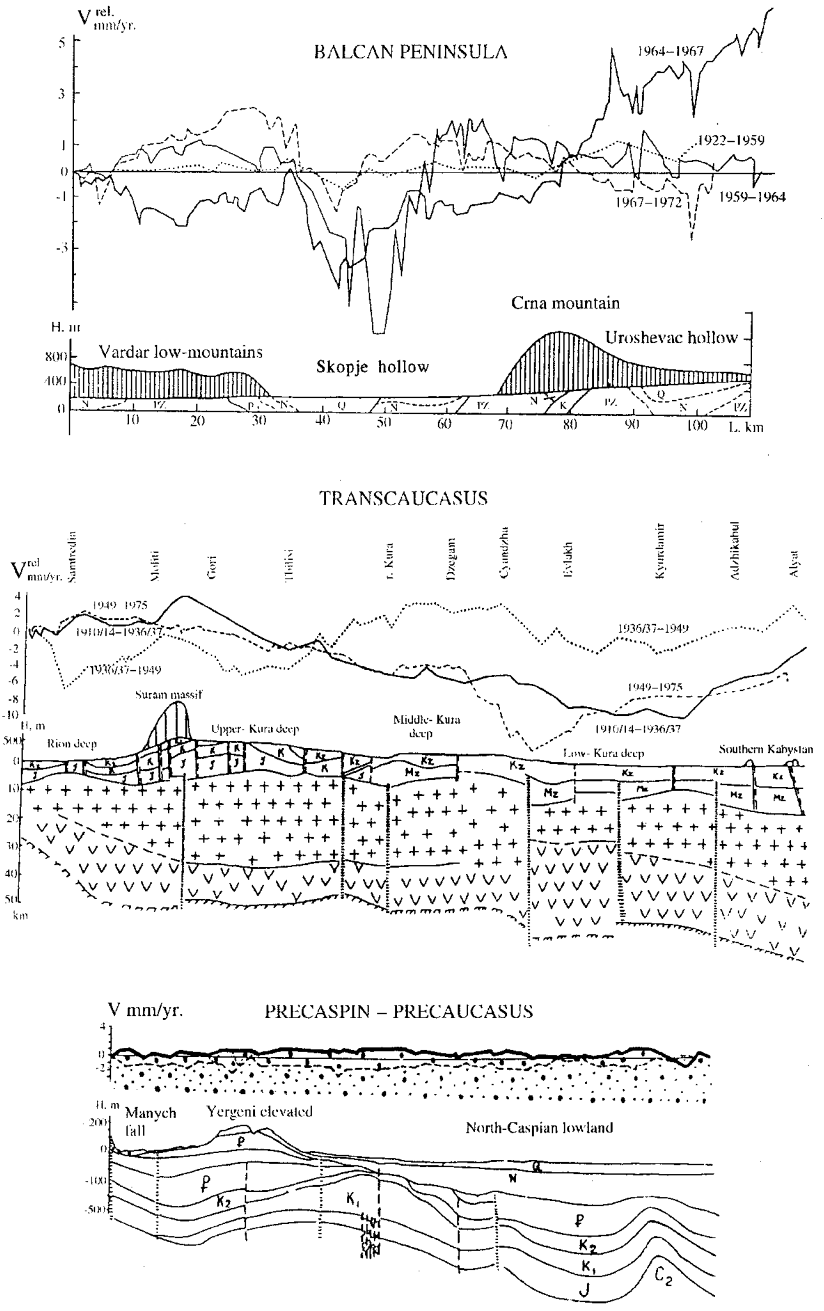

Fig. 7. Submeridional oscillation and wave movements: A — Skopje region (Balcan Peninsula), B — Transcaucasus, C — preCaucasus and preCaspian

Ryc. 7. Południkowy obraz ruchów oscylacyjnych i falowych: A — rejon Skopje (Półwysep Bałkański), B — Zakaukaski, C — przedkaukaski i przykaspijski

The oscillatory character of vertical crustal movements is also manifested in corresponding rhythmicity of other components of tectogenesis, namely in the activity of mud volcanism, seismicity, and fluid dynamics (Lilienberg 1969, 1980, 1994). Differentiated relationships between vertical movements of morphostructural blocks and the seismicity is to be noted (Ananyin and Lilienberg 1973; Lilienberg 1968, 1980, 1994). Changes in the direction of tilting of large crustal blocks precede some strong earthquakes. For instance, basing on measurements of 1910–14 and 1936/37, the Makhachkala-Derbent block in eastern Daghestan was sharply tilted to the south, causing the strong Derbent earthquake of intensity 9.0 MSK–64 scale, in its southern side. In 1936–37 and 1950 the block underwent tilting in the opposite direction, resulting in the strong Shatoy (NW slope) and Kasumkent (SE slope) earthquakes in 1966. According to levelling data collected between 1930–31 and 1959–60 and 1975, changes of tilt of the Main Ridge of the Central Caucasus (Fig. 6) coincided with the disastrous Chkhaltian earthquake in 1963, of intensity 9.0 on the MSK–64 scale. Analogous changes of tilting of blocks located on the northern slope of the Lesser Caucasus (Fig. 6) separate phases of increased seismicity in NW part of Armenia.

Traditionally, seismologists attempt to connect focal mechanisms of earthquakes with compressional stresses. However, recent measurements do show that some destroying earthquakes in Transcaucasus appear to be connected with phases of crustal extension. The catastrophic Spitak earthquake of 1988 coincides with the final phase of extension registered by levelling of 1972–1989, which replaced compression, dominating during the period of 1940–53 and 1972–74 (Fig. 8). This tendency is also proved by hydrogeological data on oscillations of the groundwater level in deep boreholes (Lilienberg and Yashchenko 1991). Deformations recorded in the epicentral area clearly reflect the mobility of small morphostructural blocks of this region (Fig. 8).

A more complicated pattern has been encountered in NW Georgia. Repeated levelling in the period of 1952–1958 registered a northward tilting of the Okriba massif, directed towards the Racha-Lechkhum suture graben which shows longitudinal extension (Fig. 9). The graben axis, however, does also show some local manifestations of uplift and compression (Lilienberg and Yashchenko 1991). This phase coincided with the strong Ambrolaura earthquake, 1940 (intensity 7.0 MSK–64 scale). Levelling data collected during 1958/59–1968/69 revealed that the trend of movements was changed in such a way that the graben became influenced not only by transversal but also longitudinal extension, resulting in general subsidence. This period coincided with regional reactivation of seismicity, culminating during the catastrophic Racha earthquake in 1991 (intensity 9.0 MSK–64 scale).

Geodetic measurements make it possible to resolve some special geological and geodynamical problems. For instance, it has been debated for a long time whether the Pyatigorsk laccolith mountain system is stable or not. The solution to this problem may help in prospection for natural resources, including thermal

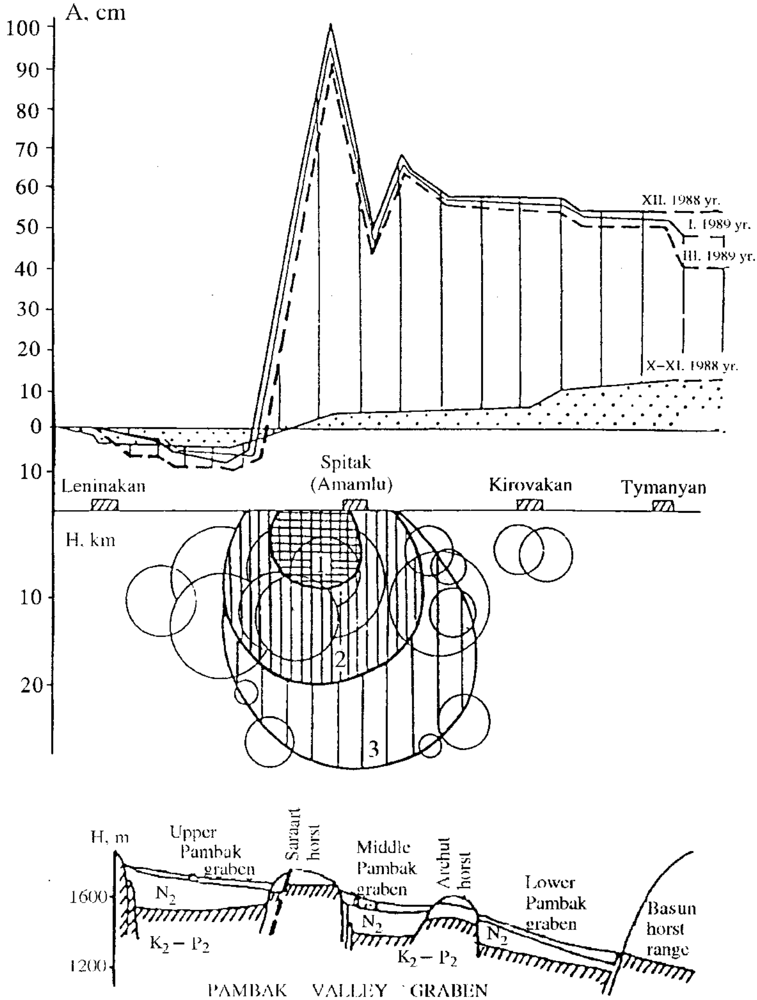

Fig. 8. Combined profile of the relationship of vertical movements, local zone of Spitak earthquake 1988 and morphostructural differentiation of Pambak graben

Ryc. 8. Złożony profil pokazujący relacje pomiędzy ruchami pionowymi, strefą trzęsienia ziemi w Spitak w roku 1988 i zróżnicowaniem morfostrukturalnym rowu Pambak

and mineral waters (Lilienberg 1980, 1983, 1989; Gerasimov and Lilienberg 1984). Repeated levelling shows that the laccolith reveals weak (up to 0.5–1 mm/yr), differentiated movements (Fig. 9).

The pulsating seismicity of Caucasus shows quasi-periodicity of 50–60, 20–30 and 10–15 years, which is in agreement with the rhythm of hydro-climatic processes. Hence, the period of intense seismicity in 1880–1890 in the Carpathian, Crimean and Caucasian regions is reflected in the changes of intensity of vertical crustal movements, as shown by mareographic data

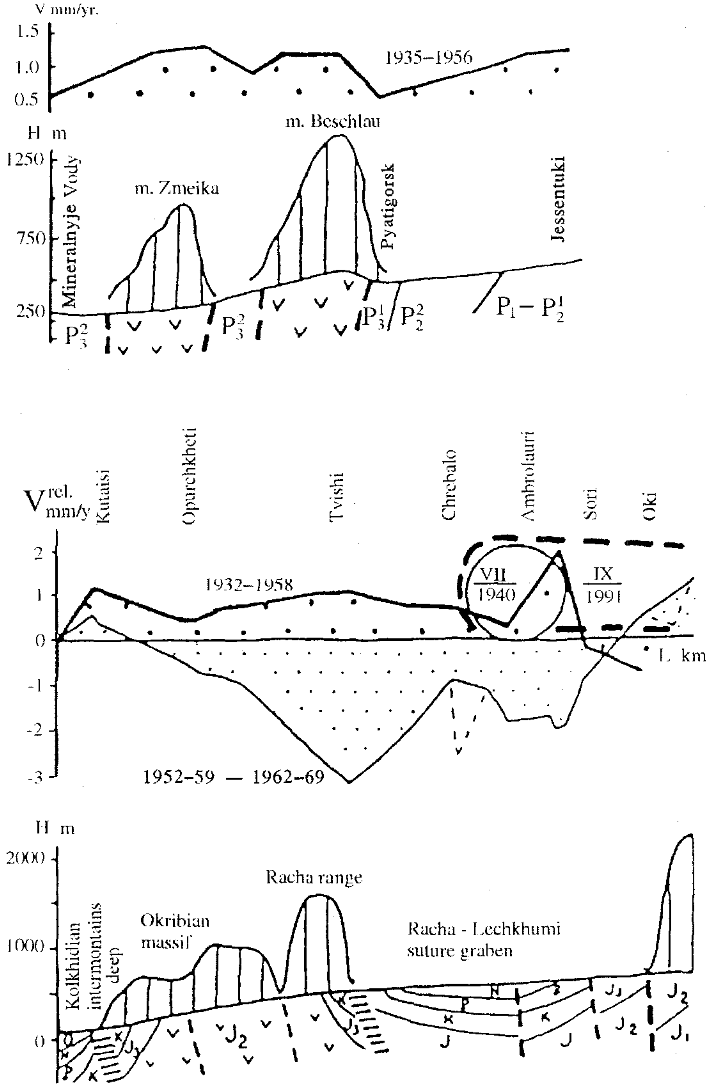

Fig. 9. Combined profiles of vertical movements of: A — Pyatigorsk laccolith mountains (North Caucasus), B — region of Racha earthquake (NW Georgia) in 1991

Ryc. 9. Złożone profile pokazujące pionowe ruchy: A — w górach lakkolitowych Piatigorska (pn. Kaukaz), B — w rejonie trzęsienia ziemi w Racha w 1991 r. (pn.-zach. Gruzja)

collected along the coast of the Black Sea (Blagovolin *et al.* 1975). The large-scale reactivation of seismicity, first in the northern parts of the Alpine orogenic belt (Carpathians, Crimea, Caucasus) and later in the middle parts (NW Turkey, Transcaucasus, northern Iran, western Turkmenia), are directly reflected in the anomalous phases of catastrophic rise and fall of the Caspian Sea level (Lilienberg 1989, 1994).

CONCLUSIONS

Instrumental measurements register high mobility of the Alpine belt of Southern Europe, alongside with its morphostructural subdivision and variation in time. Differentiation of the stress field of these orogens results from overlapping of several types of movements, including plate interactions, rotation of the Earth and focal processes. All of them point to pulsation mechanisms of alternating compressional and extensional events, the horizontal motions playing the leading role.

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REFERENCES

Ananyin I. V., Lilienberg D. A., Shchukin Y. K., 1973. *Correlation of recent vertical movements, morphostructural Earth's crust peculiarities and seismicity.* [in:] *Recent crustal movements*, Iss. 5, Publ. Acad. Sci. ESSR, Tallinn, 605–616.

Blagovolin N. S., Lilienberg D. A., Pobedonostsev S. V., 1975. *Recent vertical movements in the Pont-Caspian orogenic region.* Tectonophysics, 29, 395–400.

Fourniquet J., 1977. *Mise en evidence de movements actuels verticaux dans le Sud-Est France par comparison de nivellements successifs.* C. R. Somm. Geol. France, 5, 266–272.

Gerasimov I. P., Lilienberg D. A., 1984. *Modelles geomorphologiques du Grand Caucase: le role de la neotectonique dans l'evolution morphostructural, geodynamique contemporaine, seismicite.* [in:] *Grand Caucase — Stara Planina (Le Balcan).* Publ. Bulgarian Acad. Sci., Sofia, 9–40.

Jeanrichard F., 1975. *Contribution a l'etude du movement vertical des Alpes.* [in:] *Problems of recent crustal movements.* Publ. by Valgus, Estonia, 46–51.

Lilienberg D. A., 1968. *The main regularities on recent movements in the central parts of the Balcan peninsula.* Studia geophiz. et geodez., 12, Praha, 163–172.

Lilienberg D. A., 1969. *The recent tectonic movements and morphostructural features of mountain regions of S-E Europe.* VIII Congress INQUA, Resumes, Paris, p. 32.

Lilienberg D. A., 1980. *General and regional regularities of recent geodynamics in the Caucasus.* [in:] *Recent crustal movements.* Publ. by Naukova Dumka, Ukraine, 204–217.

Lilienberg D. A., 1983. *Problems of the recent geodynamics and geokinematics of mountain systems.* [in:] *Problems of morphotectonics*, Publ. by Bulgarian Acad. Sci., Sofia, 103–135.

Lilienberg D. A., 1985. *Regularities of recent geodynamics of the Alpine orogenic belt in the Southern Europe.* Geomorphologia, 4, Moscow, 16–29.

Lilienberg D. A., 1989. *New approaches in the study of recent geodynamics of mountainous countries.* Problems of Geography, 2, Bulgaria, 9–18.

Lilienberg D. A., 1990. *Caucasus.* [in:] *Mountains of suture zones in the USSR and plate tectonics*, Publ. by Nauka, Moscow, 141–158.

Lilienberg D. A., 1992. *Cyclicity in recent dynamics of the Aral-Pont-Caspian region and its influence on the anomaly changes of the Caspian sea level.* [in:] *7th Intern. Symp. Geodesy and physics of the Earth*, Potsdam, 3–5.

Lilienberg D. A., 1994. *New approaches to assessment of current endodynamics of the Caspian region.* Proceed. of the Russian Academy of Sciences, Geogr. Ser., 2, Moscow, 16–36.

Lilienberg D. A., Mattskova V. A., 1970. *Trends of recent vertical movements in the Lesser Caucasus and Armenian Highland.* Proceed. of the USSR Academy of Sciences, 194, Moscow, 171–174.

Lilienberg D. A., Somov V. I., 1994. *Main tendencies of recent movements and field of stress of the lithosphere of Mountaneous Crimea.* [in:] *Stresses within lithosphere.* Publ. by the Russian Academy of Sciences, Moscow, 102–103.

Lilienberg D. A., Yashchenko V. R., 1991. *Contribution of geodetic techniques to study of recent geodynamics in montaneous seismoactive territories: the Caucasus and Transcaucasus.* Publ. by USSR Committee of Geodesy and Cartography, Moscow, 55 pp.

Map of recent vertical crustal movements in Carpathian-Balcan region. 1979. Publ. by Cartographia, Budapest.

Map of recent vertical crustal movements in Eastern and Central Europe (1 : 2 500 000). 1973. Publ. by GUGK, Moscow.

Vyskočil P., 1984. *Results of recent crustal movements studies.* Transactions CSAV, Ser. Math.-Nat. Sci., 94, 8, 104 pp.

STRESZCZENIE

D. A. Lilienberg

OGÓLNE TENDENCJE I WSPÓŁCZESNE ZRÓŻNICOWANIE GEODYNAMICZNE OROGENU ALPEJSKIEGO W POŁUDNIOWEJ EUROPIE

Intensywność, trendy i współczesne zróżnicowanie ruchów tektonicznych w obrębie młodych górotworów, m.in. Kaukazu i Krymu, są przedmiotem niniejszej pracy opartej na badaniach geodezyjnych. Dyskutowany jest mechanizm kolizji płyt i zmian rotacyjnych w obrębie skorupy ziemskiej, a także mechanizm pulsacyjny występujących na przemian faz rozciągania i kompresji, które się uwidaczniają w przestrzennym i czasowym zróżnicowaniu ruchów pionowych i poziomych oraz sejsmiczności. Podkreślono występowanie zgodności pomiędzy quasi-periodycznością współczesnych procesów endogenicznych i egzogenicznych.