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Tectonophysics 380 (2004) 287–294
TECTONOPHYSICS
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Active faulting and human environment

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Accepted 28 September 2003

Abstract

Active faulting, a source of seismic disasters and ground deformation, may be also accompanied with the effects that can result in rapid or slow changes in the environment capable of affecting, either negatively or positively, living conditions of a man and in general evolution of animals and plants. Existing data still rare and uncertain show that these effects may be, first of all, specific fault-related landscapes and various geophysical and geochemical anomalies above and around active fault planes.

Keywords: Active faults; Human communities

1. Active faults and the environment

It is written a lot about seismic hazard active fault zones may cause. Commonly cited effects of active faulting and related strong seismicity are ground shaking, tsunamies and liquefaction each of them alone capable of destroying houses and killing people. At the same time, there are many other consequences of active faulting, the role of which could make a point of detailed examination. First of all, this is specific topography of the land surface affected by active fault movements. Thus, within tectonically unquiet regions, as for example the Alpine–Himalayan belt is, wide-spread active faults created numerous relatively steep slopes, linear depressions, closed or semi-closed basins and other landscape features suitable for agriculture, either providing migration routes for ancient man and thus facilitating communication between different groups of people or impeding free passage from one territory to another. There are also some data yet vague and unverified that suggest some correlation between location of long-existing settlements and linear tectonic zones and their intersections within platformic areas, as it was found for a number of presently large cities on the East European platform founded before 1300 AD (Zhidkov et al., 1999).

Principally, faults and fault zones, first of all active, may be thought to provide channels of vertical migration of different elements and thus expected to be accompanied by various geochemical anomalies or in some way change otherwise regular distribution of the elements in ground, soil, surficial or ground water. (Trifonov, 1997). Some of the evidences that this may take place were obtained in

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0040-1951/$ - see front matter © 2003 Elsevier B.V. All rights reserved.
doi:10.1016/j.tecto.2003.09.025

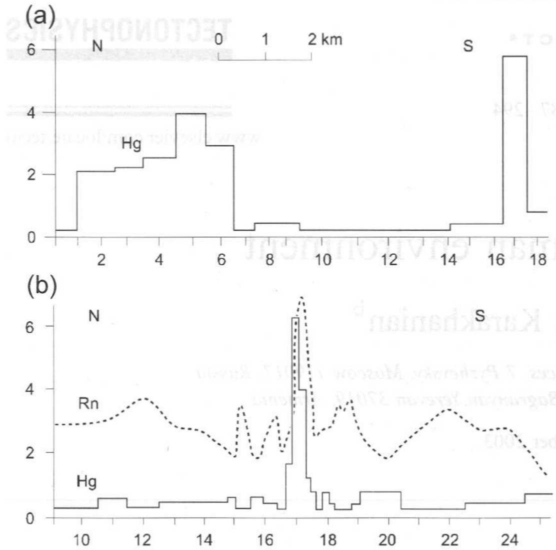

Fig. 1. Anomalies of the mercury Hg (10^{-12} g/l) and radon Rn contents in active zones of the Talas–Fergana strike-slip fault (a) and the Chon–Kurchak thrust (b) in the Tien Shan, according to the Abdullaev's data. Numbers in the horizontal axis show points of measurements. In the narrow Chon–Kurchak zone, the abnormal contents almost correspond to the fault outcrop in the land surface; the small difference between the content maxima is caused by relatively gentle fault dip and larger depth of the Rn source than the Hg one. The zone of the steeply dipped Talas–Fergana fault is wide and its central part is drained by water. So, it is characterized by the normal Hg contents and the higher contents are concentrated in the margins of the zone.

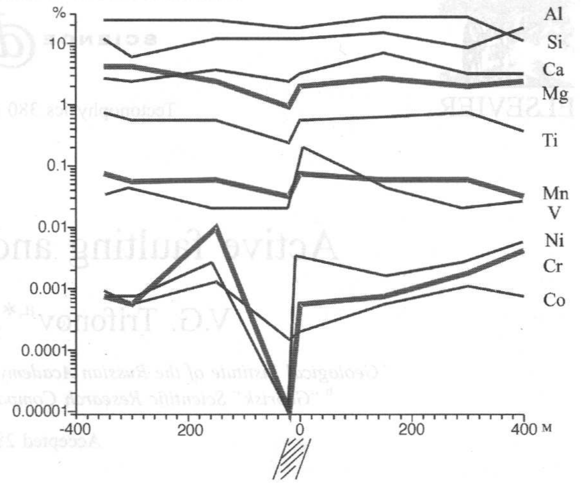

Fig. 3. Changes of different chemical element contents in soils across the Spitak 1988 earthquake fault to the SW of town of Spitak (compiled by Karakhanian).

1988 during the experiment “Tien Shan-Intercosmos-88” (Trifonov and Makarov, 1989) when variable magnetic and electrical conductivity anomalies in the active fault zones of the region were found. Abdullaev measured abnormally high contents of mercury and radon above the Chon–Kurchak active thrust, the northern Tien Shan, and the Talas–Fergana dextral active fault in the central Tien–Shan (Fig. 1). The most convincing results were obtained

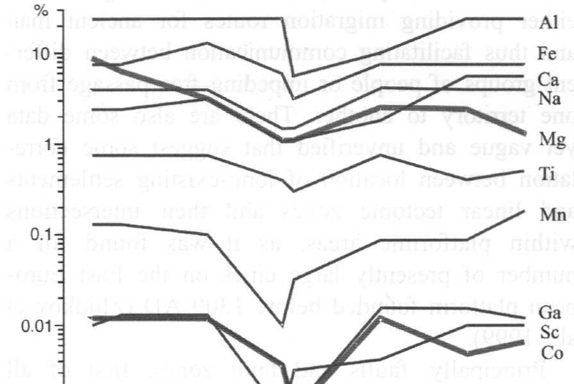

Fig. 2. Changes of different chemical element contents in rocks across the Spitak 1988 earthquake fault to the SW of town of Spitak (compiled by Karakhanian).

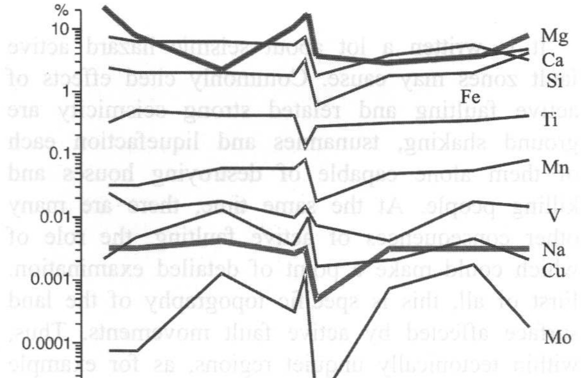

Fig. 4. Changes of different chemical element contents in plants across the Spitak 1988 earthquake fault to the SW of town of Spitak (compiled by Karakhanian).

for the Surkhob–Ilyak boundary fault zone between the Tien Shan and Pamirs: lucerne growing in fields, the fault zone goes across, contains about three times higher concentrations of Mn, As, Zr, Nb and other heavy metals than lucerne further from the zone does (Lukina et al., 1991).

More various data were obtained in the profile across the Spitak 1988 earthquake fault in the northern Armenia several years after the earthquake. At the same points in the profile, concentrations of several elements were measured in rocks, soil and plants (Figs. 2–4). Their variations partly reflect bedrock composition differences of the fault sides: the northern uplifted fault side contains the Meso-Tethys ophiolites while the southern fault side is mostly Upper Cretaceous carbonates. So, the Mg and Fe contents are higher in the northern side, and the Ca content is relatively larger in the southern side. These differences are however less distinct (and even indistinguishable for Ca) in soils and plants. Concentrations of some elements show increase toward the fault zone and then a sudden drop within 10 m from its plane (Na, Mn, Co, Se, Ga and more gently Fe and Ti). The shortage of Co decreases from rocks to soils, and that of Na and Si increases in plants. At the same time, contents of Mg and Ca closer to the fault are lower in rocks and soils within the fault zone, but increase in plants. V behaves reversely. It may be suggested that the main factors controlling variation of chemical elements here are fracturing and water circulation along the fault zone.

Some negative ions may also penetrate into the fault zone together with deep-source fluids. Increased concentrations of ^{-}Cl and $^{-4}SO_4$ were

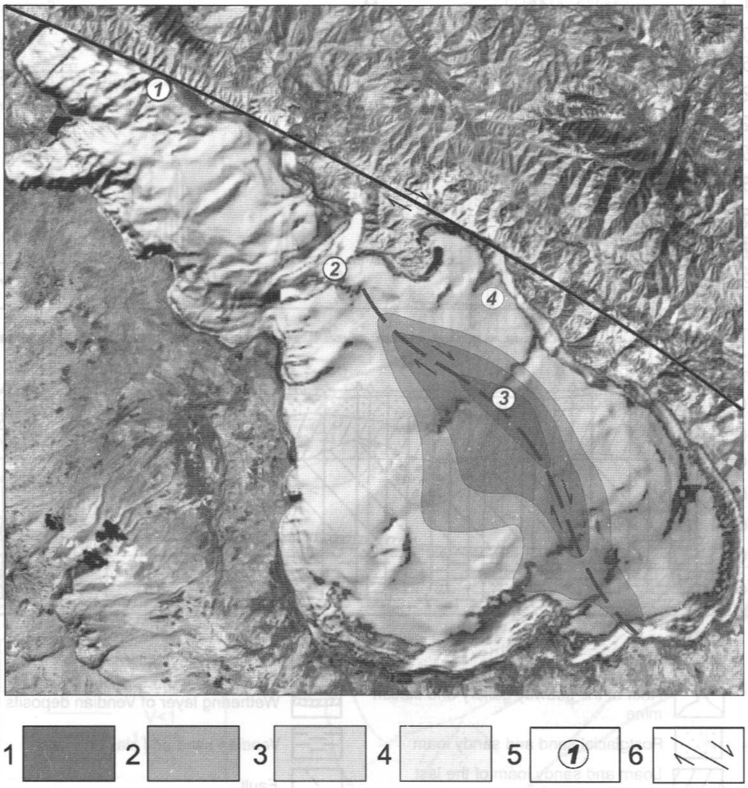

Fig. 5. Abnormal concentrations of the $-Cl$ and $-SO_4$ anions in bottom sediments and CH_4 in surficial waters of the Sevan Lake (Karakhanian et al., 2001). (1 – 4) Sites with abnormally high CH_4 concentrations; according to the Satian's data, the site three is also characterized by high (up to the 300 mg/100 g) concentration of the $-SO_4$ anion. Contours and tone intensity show contents of the $-Cl$ anion (mg/100g): >100; 50 – 100; 30 – 50; <30.

discovered in the bottom sediments of the Sevan Lake in Armenia, along the trace of the Khanarasar active fault zone. Intensive CH_4 emission was found above this and some other active faults (Fig. 5). Some correlation between weak seismicity and amount of plankton in the lake waters shows significance of the fault activity for biota (Karakhanian et al., 2001).

2. Active faults and human life

Perhaps, the anomalies described above may explain the way active faulting can influence biota and human health. Karakhanian found the abnormally high rate of some illnesses in population living close to active fault zones in Armenia. Even in the relatively stable area of the city of Saint Petersburg, the detailed investigation of faults in the sedimentary cover and their correlation with the environmental parameters revealed the oppression of biota (concentration of ill trees is three to four times higher within the fault zones than far from them) and increase in number of the cancer diseases (Fig. 6) (Mel'nikov et al., 1994). These biological and medical anomalies are probably caused in the Saint Petersburg area by high concentration of radioactive elements in the Vendian weathered rocks. The elements could reach the land surface along fractures above the faults directly from the Vendian or being redeposited in the Quaternary interglacial deposits of valleys controlled by the fractures.

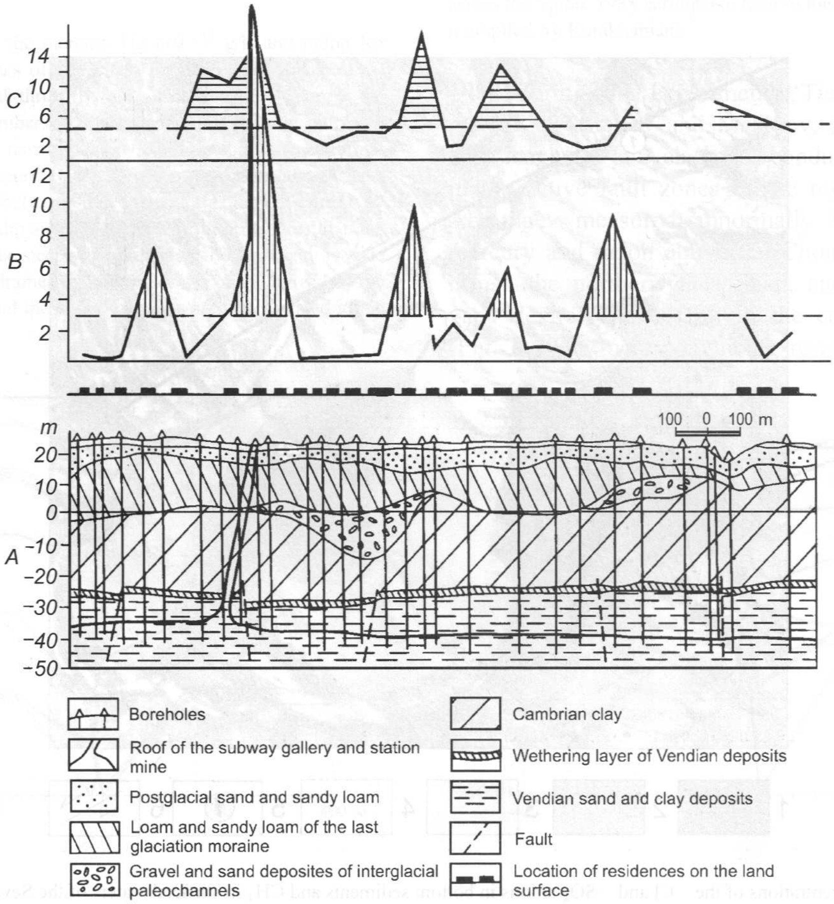

Fig. 6. Comparing of the geological section along the subway line in the Kalininskii District of Sity of Saint Petersburg (A) with the yearly number of oncological patients per 1000 men (B) and with the soil radon contents in kBq/m (C) (Mel'nikov et al., 1994).

More serious influence of active faults to biota was found by Vorontsov and Lyapunova (1984). They studied chromosomal characteristics of the fossorial rodents of the *Ellobius talpinus* superspecies. The range of the superspecies extends from the south Ukraine up to the north China and from the Kara-Kum desert up to the western Siberia. Two allopatric karyomorphs represent the superspecias. They are *E. talpinus s. str.* ($2n = NF = 54$) in the west and *E. tancrei* ($2n = 54$; $NF = 56$) in the east. However, near the Surkhob–Ilyak active fault zone in the Pamirs–Tien Shan boundary, the *E. talpinus* superspecies show uniquely wide chromosomal variability with the constant $NF = 56$: 24 karyomorphs with $2n = 31–54$ were identified there (Fig. 7). Vorontsov considered this as one of ways of the new species formation. It was the saltational genetic mutation that was manifested by the chromosomal variability and was followed by the period of divergence and fast fixation of the changes.

The same Robertsonian variation was found for mole rats *Microspalax leucodon* in active zones of Bulgaria, Yugoslavia and Turkey and *M. ehrenbergi* in the Levant fault zone of Israel, Lebanon and Syria. The house mouse *Mus musculus* (stable karyotype is $2n = NF = 40$) demonstrated chromosomal variation near active zones in Italy (Capanna,

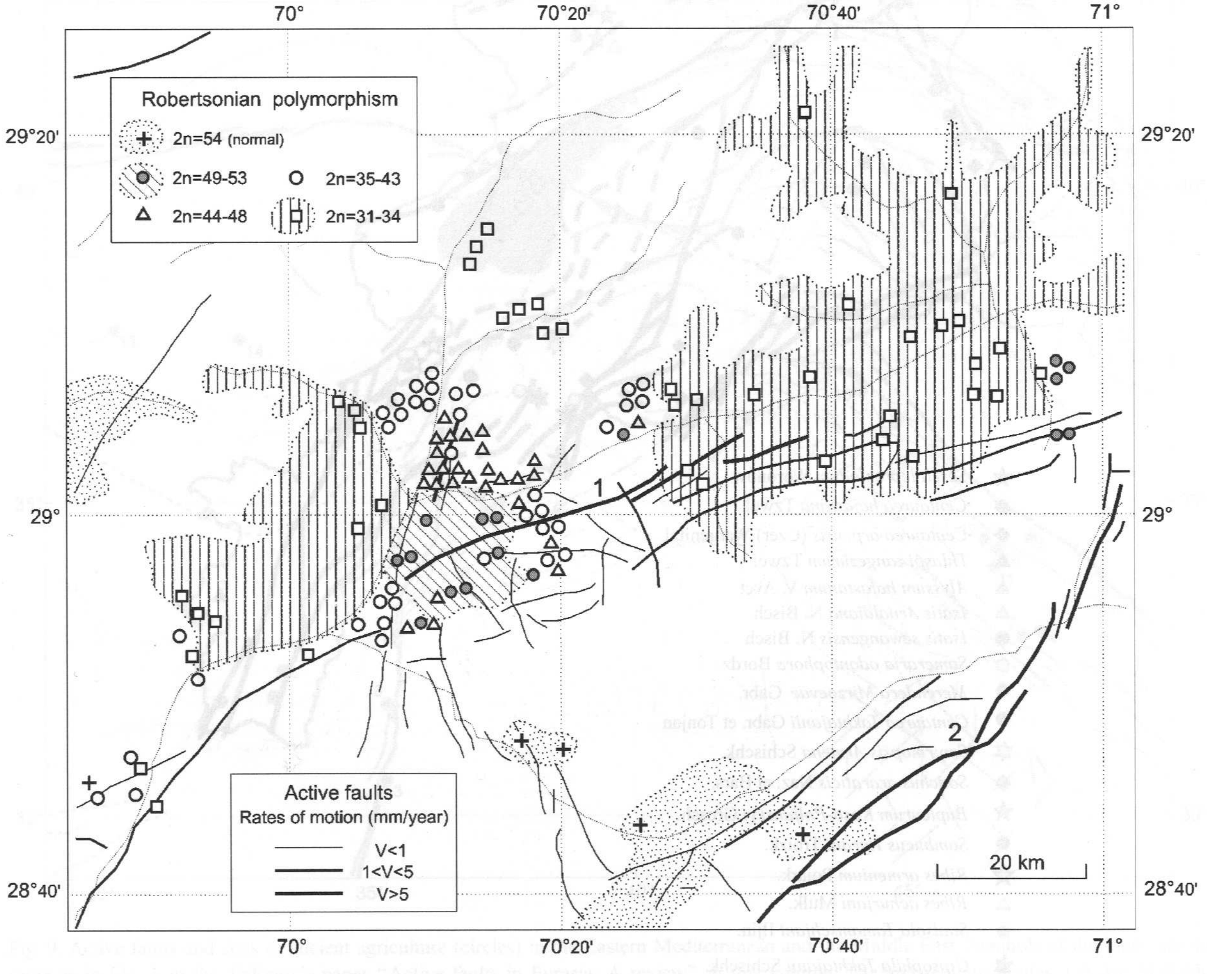

Fig. 7. Active faults in the Pamirs – Tien Shan boundary (Trifonov, 1997) and chromosomal variability of the fossorial rodents of the *E. talpinus* superspecies in the region, after (Vorontsov and Lyapunova, 1984). The Robertsonian variation is characteristic for the Surkhob–Ilyak thrust zone, but not for the Darvaz–Alai strike-slip zone (probably, because of absence of the detailed studies in the latter).

1982) and the subalpine voles *Pitymys daghestanicus* showed the same in the Transcaucasus, particularly near the Khanarassar active fault zone (Lyapunova et al., 1988). The mutant form of Y-chromosome and some other chromosome anomalies of voles were found in active zones in the southern Italy, Yugoslavia, the Tien Shan, the Altai, the south of the Baikal rift, Kunashir and Shikotan islands of the Kuriles, Hokkaido, Honsu, and the northern Andes; and the pocket gophers demonstrated the variation near active zones of California, Oregon and Washington states (Vorontsov and Lyapunova, 1984).

Karakhanian found a concentration of the endemic plants near active zones in Armenia that also may be interpreted as their mutation effect (Fig. 8).

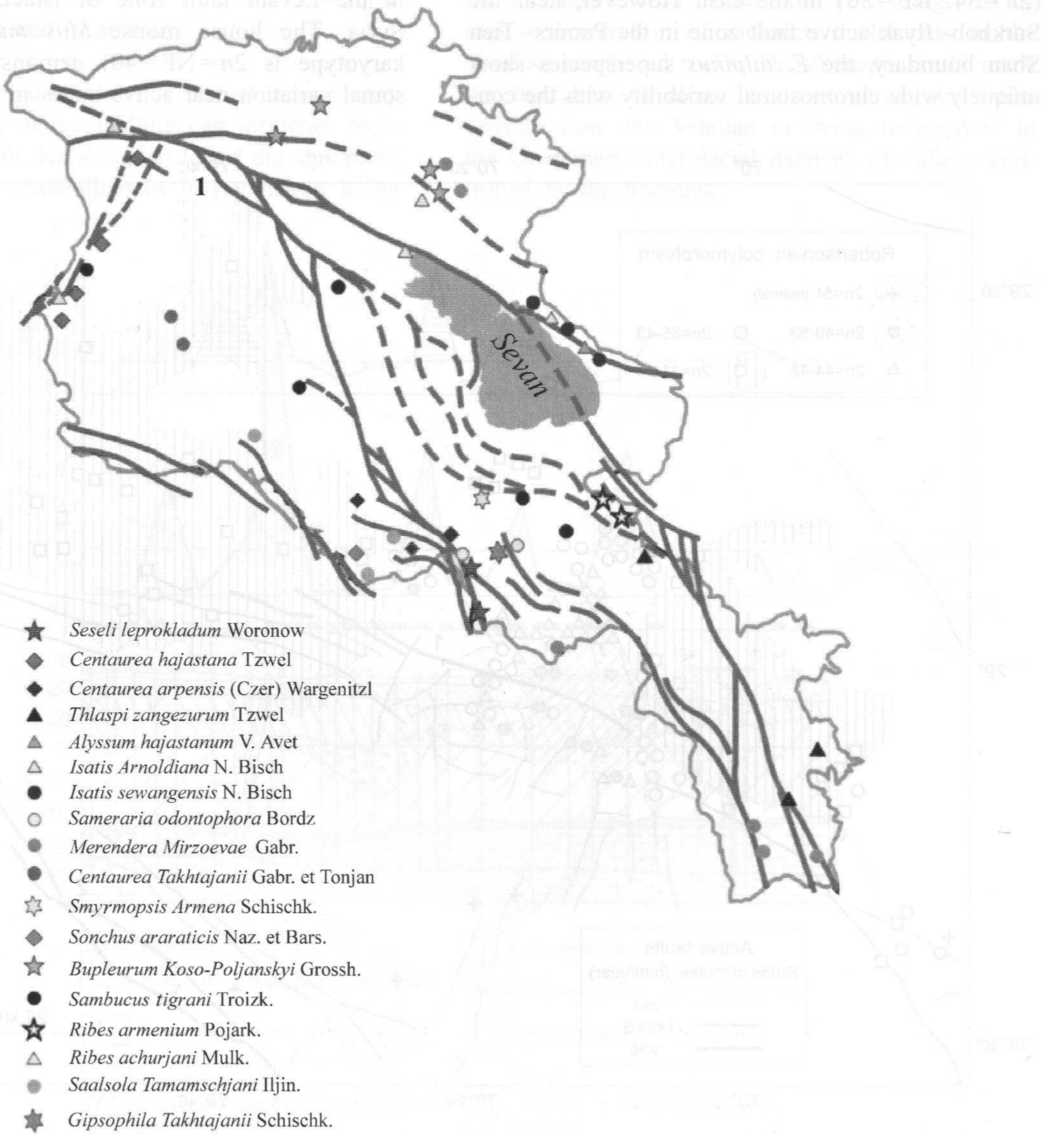

Fig. 8. Active faults and distribution of the endemic species of plants in Armenia (compiled by Karakhanian with using the "Red Book of Armenia").

Active faulting can influence the human life and social development, first of all, as a source of strong earthquakes and accompanied phenomena such as ground deformation, landslides and sometimes volcanism. At the same time, active faulting has been a natural source of not only disasters. In Fig. 9, the active faults of the Eastern Mediterranean and the Middle East are shown together with the archaeological sites with evidence of the oldest agriculture. They are dated back to the second part of IX and VIII millennia BC (Mellaart, 1965). All the sites (except that of Chatal Huyuk in Turkey) are located near active fault zones or (as partially in Zagros) in basins, which are bounded by active anticlines with blind thrusts in cores. The generation of agriculture was the principal step in the human history and is often named "the Neolithic revolution". It had been prepared by the climatic improvement that followed the last glaciation and appearance of permanent settlements and necessary implements during the previous collecting of plants. However, the presence of good soils in suitable fields, sources of water and the seed material for planting, which were also necessary for the agriculture, is related to active tectonism. Active faults formed steep bounds

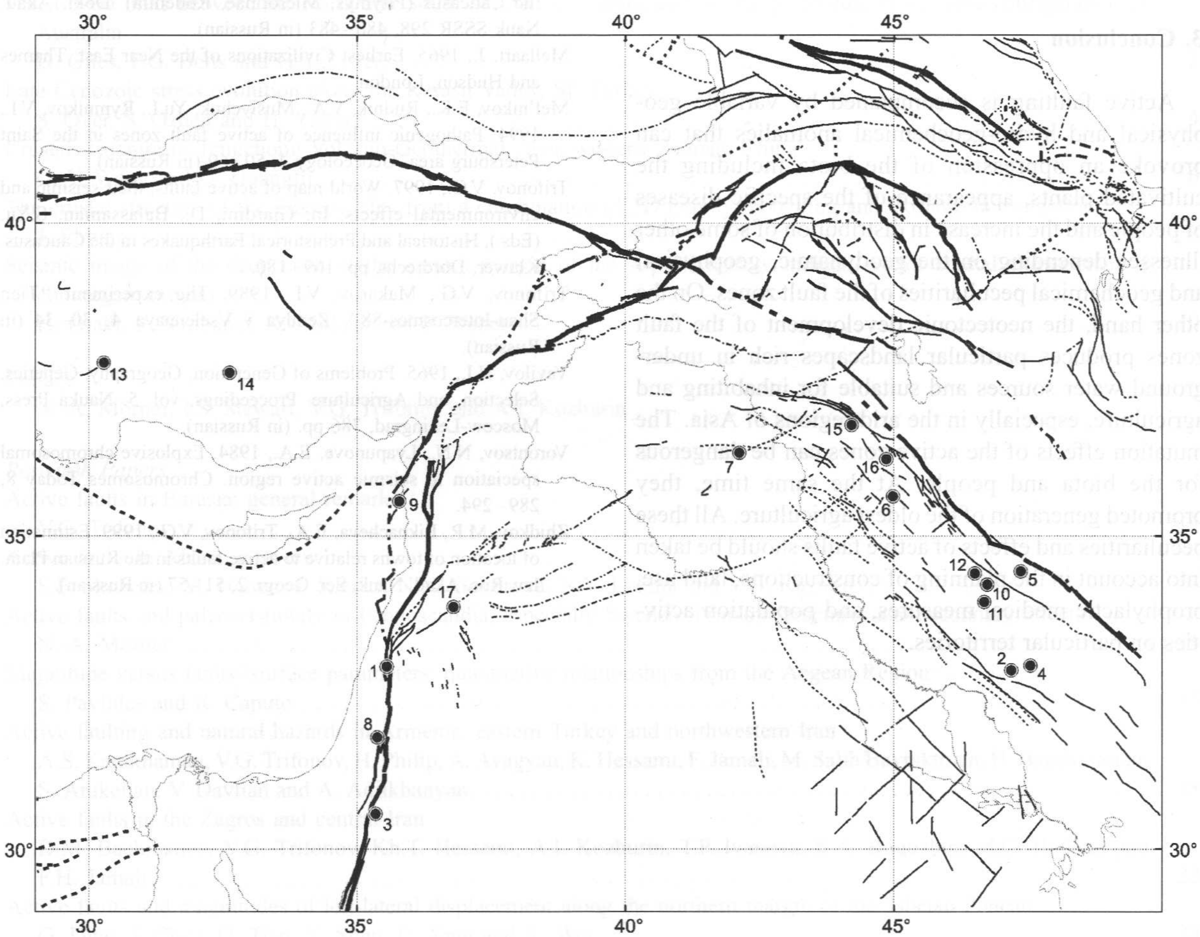

Fig. 9. Active faults and sites of ancient agriculture (circles) in the Eastern Mediterranean and the Middle East. Symbols of the faults are the same as in Fig. 1 in the Trifonov's paper "Active faults in Eurasia: A review" in this volume. The archaeological sites: (1) Ain-Mellakha (Einan); (2) Ali Kosh; (3) Beidha; (4) Bus Morde; (5) Ganj Dere; (6) Jarmo; (7) Jebel Magzalia; (8) Jericho; (9) Ras Sharma (Ugarit); (10) Tepe Asyab; (11) Tepe Guran; (12) Tepe Sarab; (13) Hacilar; (14) Chatal Huyuk; (15) Shanidar and Zavi-Chemi; (16) Shimshara; (17) Yabrud.

of intermountain basins and foredeeps with springs and good soils on alluvium. The adjacent uplifting ridges delayed the western cyclones and caused raining over the basins. All the sites of the oldest agriculture were found in the regions with wide distribution of wild ancestors of the cultivated plants (Vavilov, 1965). Vavilov distinguished some areas within the regions where different eatable plants of many species and forms grow together. The areas were situated within or close to the active fault zones that may have been sources of mutation effects. It helped the ancient farmers to find plants which are most productive.

3. Conclusion

Active faulting is accompanied by variable geophysical and hydro-geochemical anomalies that can provoke an oppression of the biota including the cultivated plants, appearance of the specific diseases of people and the increase in distribution of some other illnesses depending on the geodynamic, geophysical and geochemical peculiarities of the fault zones. On the other hand, the neotectonic development of the fault zones produces particular landscapes rich in underground water sources and suitable for inhabiting and agriculture, especially in the arid regions of Asia. The mutation effects of the active zones can be dangerous for the biota and people. At the same time, they promoted generation of the oldest agriculture. All these peculiarities and effects of active faults should be taken into account in the planning of constructions, land use, prophylactic medical measures, and population activities on particular territories.

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