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ACTIVE FAULTING AND RELATED SEISMIC HAZARD IN THE VANADZOR DEPRESSION AREA

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Institute of Geological Sciences, M.Baghramian Ave., 24a, 0019, Yerevan, Republic of Armenia, e-mail: avagn@yahoo.fr

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Active faults in the Vanadzor depression area present evidence of high hazard level. The well understanding of the hazard characteristics of these faults is the first and important stage to prevent related risk. The important point is the maximum permissible hazard level estimation equivalence to the real hazard, which is not a case in urbanization planning for Vanadzor area. Risk level is high taking into account the seismic potential, interrelated natural, technologic or anthropogenic hazards in the densely populated area. The obtained data shows one paleo-event with magnitude Mw≥7.2 with epicenter in the Vanadzor depression area. The existence of the surface rupture in the basin is proven. Thus the active segments must be considered as capable faults. Manifested fault activity as a main triggering factor of interrelated hazards indicate the importance of the continue investigation in one hand and the sensibilization of the republican and local authority on the other hand.

1. Vanadzor depression setting

The Vanadzor depression situated in the most important 490 km length Pambak-Sevan-Sunik fault (PSSF) zone of the Armenia, striking from Lake Arpi (NW Armenia) area to the valley of Arax (SE Armenia). To the NE from Sevan lake the fault activity forms tectonic depressions (of Tsovagugh, Fioletovo and Vanadzor) (figure 1). The trace of PSS strike-slip fault is partly inherited from major thrusts and reverse faults which deformed the Lesser Caucasus range since the beginning of continental collision of the SAB with the Eurasian margin during Paleocene to Lower Eocene (Avagyan et al., 2009; Sosson et al., 2009).

The activity of the PSSF fault is studied since the Spitak 1988 earthquake (Trifonov et al., 1990; Philip et al., 2001; Karakhanian et al., 1997, 2002, 2004; Avagyan, 2001). These studies demonstrated that the PSSF consists of five large segments. Vanadzor depression of 16 km long and up to 3 km wide situated in the overstep zones of the 90-km-long Arpi–Vanadzor and the 115-km-long Vanadzor–Artanish segments between the mountain range of Bazum to the North and that of Pambak to the South. The Western half of this depression is occupied by the Vanadzor city (the third city of Armenia). Horizontal slip rate estimates are 3–4 mm/year for the Arpi–Vanadzor segment (Trifonov et al., 1990) and 2.8 mm/year for the Vanadzor–Artanish segment (Philip et al., 2001).

Contrary to the horizontal kinematics of right lateral strike-slip the PSS faults shows variable vertical one. Along its southern segments PSSF generally manifests mainly oblique slip with normal component, whereas along the northern ones is exposed reverse component. This can be explained by progressive change of the fault orientation from the N105° (in the North) to N155° (in the South) in correlation with stress field (Avagyan, 2009).

The fault is characterized by strong historical earthquakes that occurred most notably in 915 (M~6.0), 1407 (M~7.0), 1187 1853 (M~6.0) and 1139(M~7.5–7.7) (Karakhanian, 2004). The paleoseismological study evidenced paleo-earthquakes of magnitude Mw=7.4 for Vanadzor–Artanish and Arpi–Vanadzor segments, which are the maximum estimated magnitudes (with respect to historical and instrumental seismicity) for these segments according to observed coseismic displacement (Avagyan, 2001; Philip et al., 2001; Karakhanyan et al., 2004).

In the Vanadzor area there are scare witnessings about earthquake disaster. According to Galagyan (1858) the Goir monastery is totally destroyed by 1828 earthquake that the epicenter is situated about 18km to the south. Mesropyan (1984) suppose that the wonderfully constructions (supposed to belong to the 9th century) in the abandoned Papunk village (south of Vanadzor city, in more altitude), the churches (only fundaments conserved) in the villages of the Verin Kilisa and Lernapar were destroyed by earthquake. All this sites need to be investigated in detail. Excepting the seism of 1828, we don't now the others destruction caused earthquake date and epicenter situation.

Instrumental catalogues of earthquake (NSSP) include only single seism of moderate magnitude (5.3) occurred in 1915 in this area.

2. Geomorphic evidence of fault activity

The PSSF (Pamak-Sevan-Sunik fault) in the Vanadzor depression the fault is subdivided into several branches controlling almond-shaped basin (figure 2). The depression substratum composed by sedimentary rocks of Eocene and Upper Cretaceous (limestones, tuffs, tuffo-breccia, sandstones) and post Oligocene intrusive rocks (Sayadyan, 2009). More recent sediments of clay and send occupy the bottom of the depression and attain 145 meters thickness. Two volcanic levels of tuff acknowledged in borehole in depth of 16.7m and 23.8m in the NW of the basin (Milanovski, 1968). In the geological construction of the depression the existence of basalts andesitic (Bagdasaryan and Jrbashyan, 1970) is important from geodynamical point of view which disappear westward under the Pambak river recent alluvium.

Vanadzor depression crossing the major fault traces are identifiable on the 3D numerical model (figure 2), on topographical maps and air photographs. The field observations show that the rocks of the substratum of the basin between the main faults are deformed and frac-

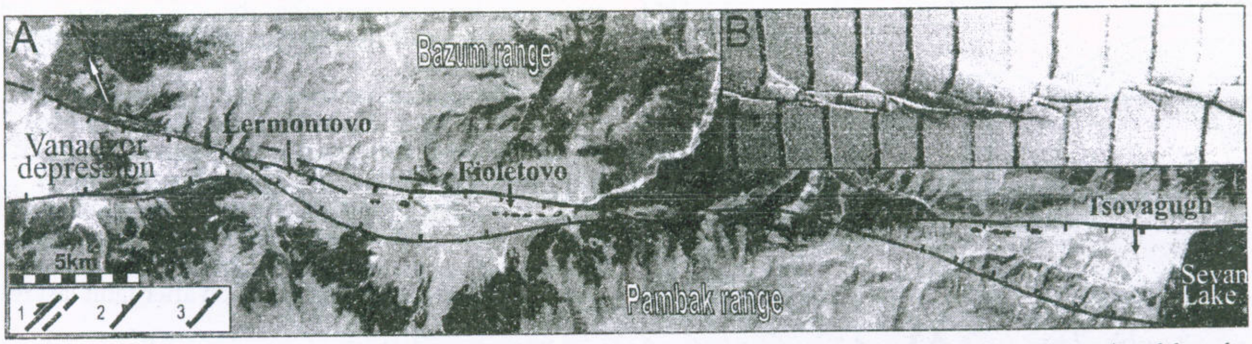

Figure 1. System of active faults forming tectonic depressions proposed by A.Karakhanyan (A). B- Physical experimental model results on sand realized by J.Ritz (Montpellier II University, France) for the strike-slip fault. 1- strike-slip faults, 2- reverse faults, 3- normal faults.

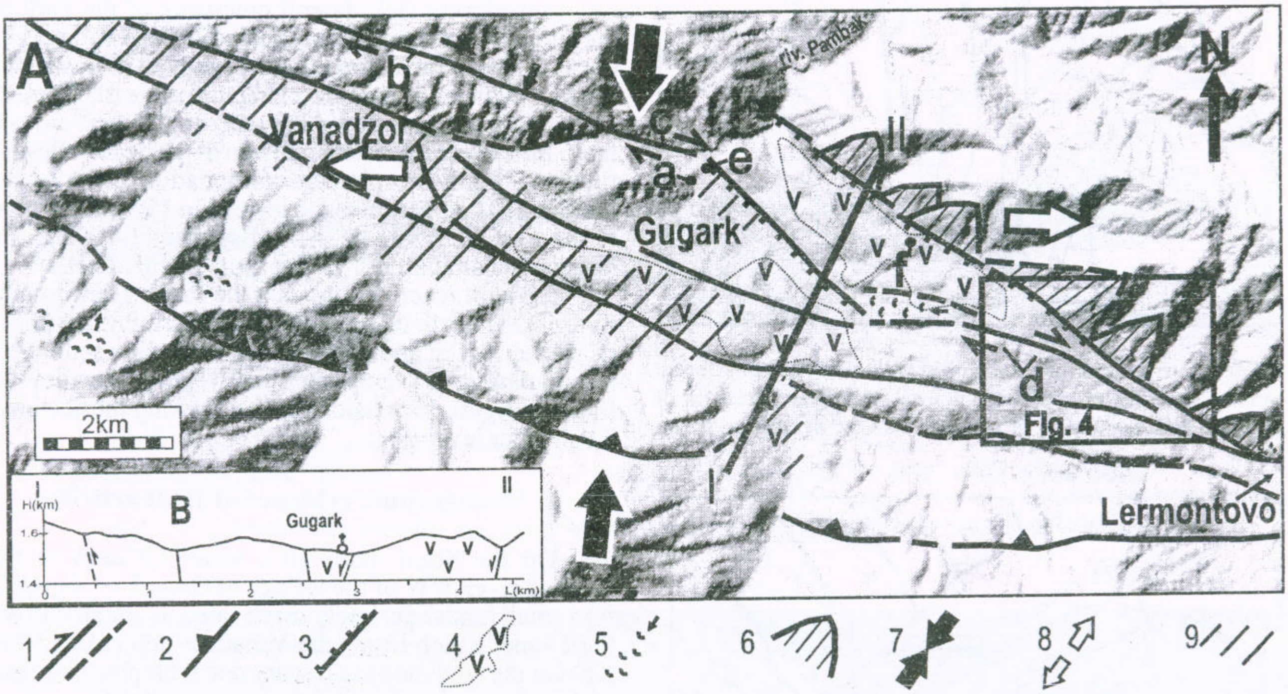

Figure 2. A-Active fault map superposed on the 3D topographic model (modified from Avagyan, 2001). 1- active and inferred strike-slip faults, 2-reverse faults, 3-normal faults, 4-basalte andesitic, 5 – landslides, 6-triangular facets, 7- regional compression axes, 8- local extension of Right bend, 9- peopled area. B- topographical profile (the I-II line of profile is shown on numerical model) with vertical exaggeration, faults and basalts andesitic situation are shown.

tured in a very intense manner especially at neighborhood of faults.

One such intense deformation outcrops to the West of Gugark village (figure 3; a, figure 2). Paleogene sediment layer become vertical affected by the faults. Schistosity intensified to the SW and the original layer structures are nearly disappear. The fault has a general flower structure and near the surface manifests different cinematic. This cinematic variability is observed on the fault map depending of segment geometry and orientation. In the same area the numerous striated micro-faults are observed allowing stress tensor calculating using the Etchecopar software (1981). The σ_1 orientation is compatible with the regional compression axe obtained by former study for the region (Avagyan et al., 2005). The outcropping WNW oriented schistosity additionally confirms it. Fault morphological expressions as pressure ridges, deflected deranges, offset streams, triangular facets evidence the recent activity. The fault main segment dextrally offset the stream 400m (b, figure 2, A) and more than 1,3 km deflected the NE oriented valley of Pambak river (c, figure 2, A) to the north of Vanadzor city.

In the East part of the Vanadzor depression, the fault escarpments and the deformed morphological markers are better conserved than in the West owing to lesser volume of the covering recent sediments and to less anthropisation.

The valleys which go down from the Bazum Mountain are well developed in the relief with relatively dip V shape erosions, but they stop very roughly at the limit of the basin which is a one segment of the fault. Here triangular facets developed indicating relative subsidence of southern block (A, figure 2). This transition slop/basin underlined by springs corresponds to the fault limiting the depression from North (figure 4). Towards down-

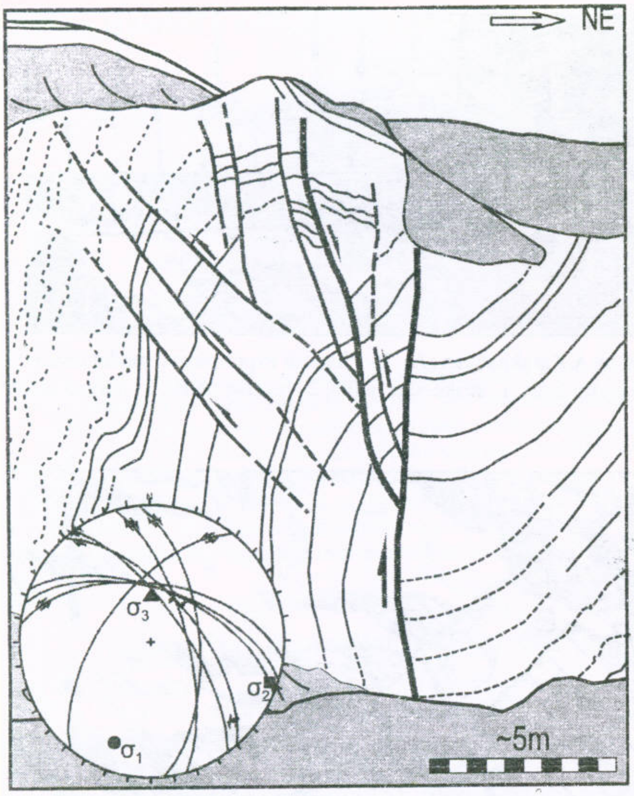

Figure 3: Interpretation of an outcrop in NW of the village of Gugark showing the complexity of the fault near the surface. Stress tensor obtained from population of micro-faults near the village shown below.

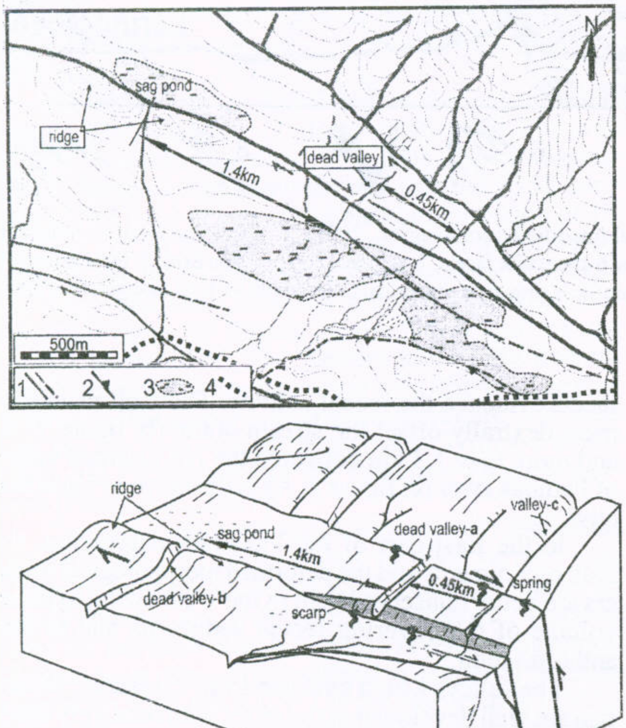

Figure 4: The map and the block interpretative diagram of the East part of the Vanadzor basin (modified from Avagyan, 2001 and Karakhanyan et al., 2004). 1- Active and inferred faults, 2- reverse faults, 3- high humidity area, 4- road.

stream the incisions are rather shallow or absent. Somewhere recent small alluvial fans related to important valleys are observed.

Still towards downstream (SSW) the glacis is interrupted by another fault. It to the East manifests 2-6 meters height southward dipping scarp and to the West 25 meters height northward dipping scarp (figure 4). This reversed scarp phenomena shows fault segment strike slip kinematic nature which displaces a paleo-topography. The started new perpendicular incisions on the straight scarps show recent erosion after fault last reactivation.

These two faults limit one dead valley incising the glacis without possible upstream and downstream continuation (*a* on the block diagram, figure 4). This disposition can by explained only by a lateral offset.

Considering right lateral cinematic of the fault in the site, downstream continuation of *a* dead valley (figure 4) can be the abandoned valley (without its upstream) starting in the middle of the elongated ridge (d, figure 2, A; b, figure 4; figure 5) 1,4 km more to the West along a fault. Relatively important incision of the dead valley (a, figure 4) imply its upstream continuation on the southern slope of the Bazum range located in 450 meters more to the East (c, figure 4). This disposition implicates a horizontal cumulative 1,85 km right lateral offset.

The fault reactivations dam the streams and humidity from the north of elongated ridge forming sag pond. Its surface is flat and corresponds to the fine sediments accumulation in a temporary lake. The dead valley (b, figure 4; figure 5) incision restarted owing the accumulated water level rise.

3. Stratigraphic evidence of fault activity

On the South bank of a small affluent of the Pambak river, NW of the village of Gugark (e, figure 2, A) a small landslide, lately reactivated, is situated in the fault zone, which limits the Vanadzor depression from NE. On the landslide main scarp one fault plan cuts near surface formations with the strike parallel to the suggested main fault segment located more to the North (A, figure 6). At least six stratigraphic units are identified (figure 6):

1-Unit of clear clay;

2-Unit of alternation of the fine clay and sand (few angled elements of diameter <1cm);

3 and 3A - lower Paleosoil. Clay unit (3), is darker below containing numerous nodules of carbonate of pedologic origin and dark brown soil developed on top of it (3A);

4-Unit of colluvion with gravel of centimetric size;

5- Upper Paleosoil discordant bedding on units 3 and 4;

6- modern Soil.

The C^{14} dating (realized in the laboratory of Hydrology and Isotopic Geochemistry of the University of Paris - South by J-L. Michelot) of carbonate sample taken from the unit 3 (figure 6) gave an age of 21705±240y B.P. Another sample of the charcoal taken at the root of the actual soil (6) gave a very recent age of 132 ± 51 y B.P (dated in the same laboratory).

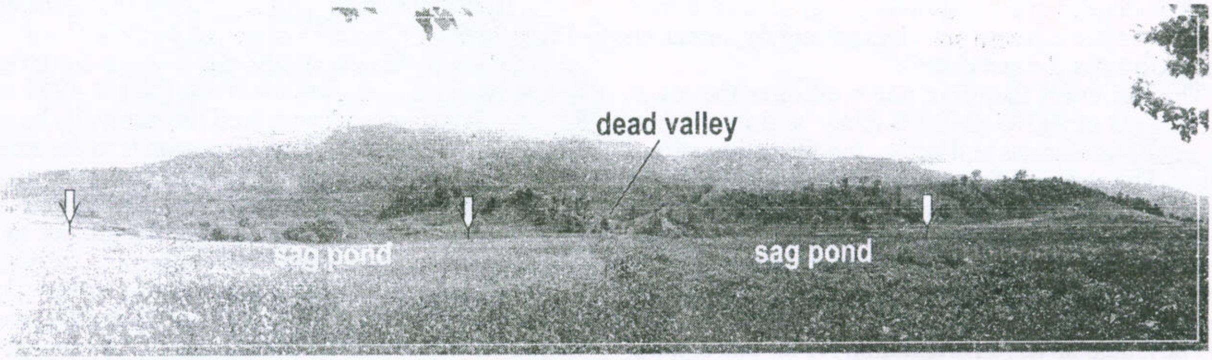

Figure 5. Photo of the elongated ridge with the paleo-valley. The arrows point out the fault trace.

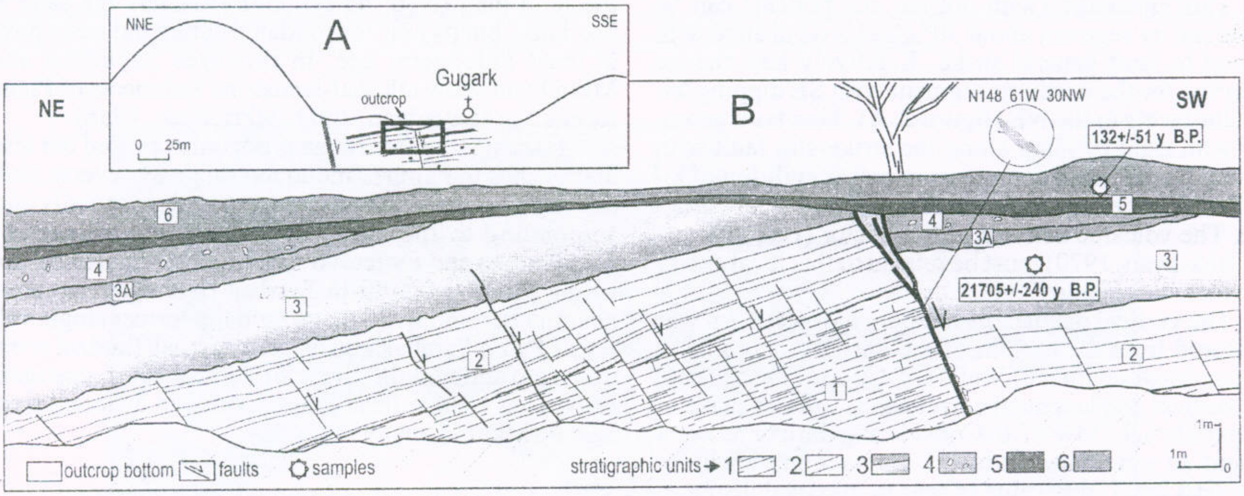

Figure 6: A-Schematic chart showing the situation of outcrop in comparison with the main fault. B- Map of outcropping.

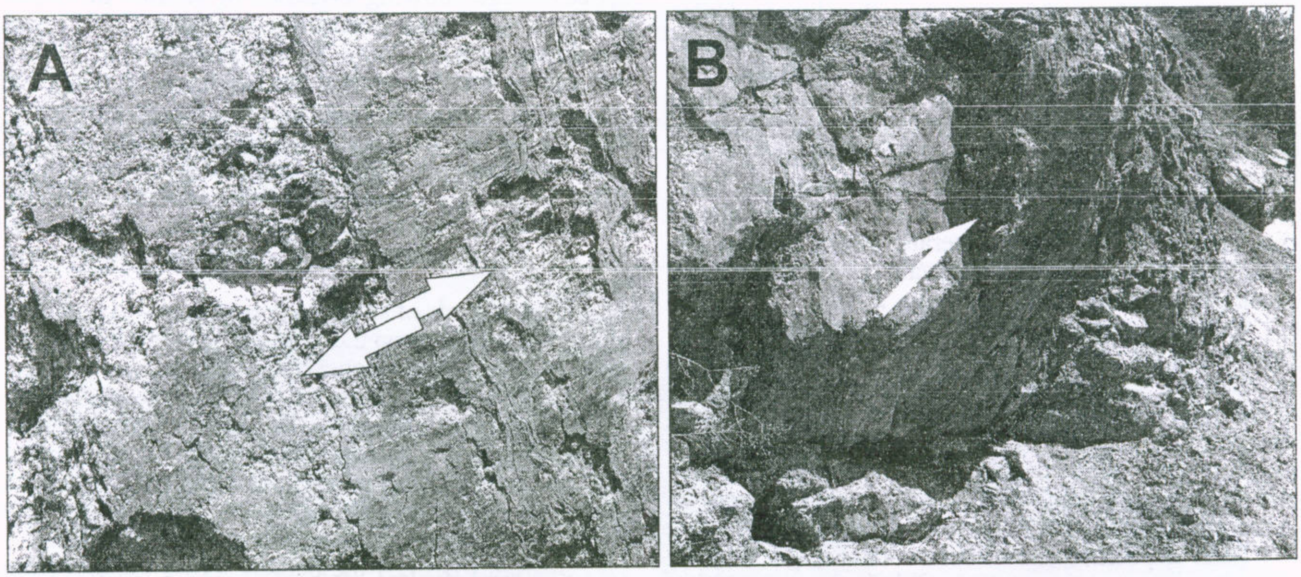

Figure 7. Oblique –slip (A) and reveres (B) faults to the north of Lermontovo village.

Discussion

Units 1 and 2 of clay and sand correspond probably to the Plio-Quaternary formations which fill the basin. They are affected by numerous normal micro-faults with displacements lower of 30cm and covered by an ancient thick soil (3 and 3A). These faults point out at least one seismic events occurred before the paleosoil formation.

The units 1, 2, 3, 3A, and 4 are tilted to the NE related to the normal fault which affects them and the main fault which is more in NE according to morphological evidences. The erosion partly removed the units 3A and 4 before modern soil (units 5 and 6) formation which postdates the last event.

The last event therefore occurred after the lower paleosoil (3) of 21705±240y B.P. age and unit 4 (not well dated) formations and before the formation of unit 5 and 6. The charcoal from unit 6 has a very recent age (132 ± 51 y B.P.) giving thus large time interval for the last seismic event. In any case this event is recently occurred in upper Pleistocene or in lower Holocene proving the fault activity and the real danger for the populated area.

The fault plan has an orientation N148° and dipping of 61°W. The identified striations have a pitch of 30 ° NW that corresponds to an extensive and predominantly strike slip fault (transtension).

This cinematic (with normal component) can be explained by segment about 30° clockwise change with respect to fault general strike. Relatively less change observed for the northern segment with SE dipping triangular facets to the NE (figure 2, A). This fault geometry with right bending along the strike-slip fault with general North South compression crate condition of local East-West extension zone forming pull a part structure. The volcanic activity of this sector (Bagdasaryan and Jrbashyan, 1970) must be related to this local extension tectonics (figure 2, A).

The vertical displacement equal to 2.40±0.2m was measured from the bottom of the unit 3. According to the empirical relation of Wells and Coppersmith (1994) this vertical displacement corresponds to earthquake of magnitude 6.9 <Mw <7.0. Considering horizontal component of cinematic induced displacement will be Mw=6±0.2m. If this value is near to maximal displacement, the corresponding magnitude for transtensional fault (all type) will be of Mw=7.26±0.1 and for average displacement it will equal to Mw=7.56±0.1. Such a magnitude can break the surface over more than hundred kilometers, which means that the rupture are propagated over two nearby segment (Vanadzor-Artanish and Arpi-Vanadzor). The same conclusion we obtained according to paleoseismological data from Gogaran and Fioletovo trenches situated about 28 km to the NW and 16 km to the SE from Vanadzor depression center (Avagyan, 2001; Karakhanyan et al., 2004). The previous studys shows that for same site the PSSF generates strong earthquakes with long recurrence time intervals (about 1500–4000 years) (Philip et al., 2001; Davtyan, 2007).

During a major earthquake the Vanadzor depression would not play a role of barrier in the case of both overlapping segments break. The uninterrupted aspect of the most active branch of the fault crossing the whole depression (figure 2) and linking up the segments of the Gogaran area (segment of Arpi-Vanadzor) to the NW and of the Fioletovo area to the SE (segment of Vanadzor-Artanish) arguments for that statement.

This disposition recalls the evolved stage of a fault zone obtained experimentally by Tchalenko et al. (1970). In the first stage the displacements split on several disconnected fault segments at the surface but linked in depth to the main fault. Later the most part of the segments become inactive while displacements concentrate on an uninterrupted fault located above the deep fault (master fault).

Another interesting outcrop is identified to the north of Lermontovo village. Here strike-slip fault (N100° 90° 19°W DF) with vertical component (oblique slip) (figure 7) and North dipping reverse fault (N115° 49°N 62°E RF) are identified both with well mechanically striated fault plans. The outcrop site corresponds to the eastern limit of the Vanadzor depression (Tandzut river upstream) where the faults are manifested in the narrow zone. The activity of the strike-slip fault which continues to the WNW we have aforementioned. Concerning the reverse fault we identified nearby outcrop with stratigraphical evidence of past activity (figure 8). Here brecciated and altered andesites and its piroclastes of Eocene age (4, figure 8) come up to the non consolidated sand and clayey sand (3, figure 8). Some materials of the tuffs have fallen in the sand (3, figure 8), that is why we observe it near the fault plan (N80° 45°N). Unfortunately the sand is not dated, but its non consolidated nature indicates post, at least Paleogene age. In this area Sayadyan and Mkrtchyan show alluvial-lacustrine sediments of Pleistocene age (Sayadyan, 2009; Mkrtchyan, 1956).

Bazum mountain range is not only uplifted but also approaches to Pambak mountain range by reverse fault activity (figure 9). The intermediate area is actually corresponding to the segment between the villages of Lermontovo and Fioletovo submitted to differential uplifting (maximal uplift in Tandzut river upstream area, near the Lermotnovo village) and the former single valley of Paleo-Pambak consisted by actual Tandzut river, upstream and middle course of Pambak river, upstream of Aghstef river valleys is subdivided in different river basins (Mkrtchyan, 1956).

4. Archeo-seismological observations

In the Vanadzor area we have observed an abandoned village showing evidence of seismic influence partially discussed before by Avagyan (2001) and Karakhanyan et al. (2004). After Hakobyan et al. (2001) this village situated several km NE from the village of Gugark (f, figure 2, A) is called Mets Baker. In this medieval historical site numerous khatchkars (curved stone with cross) appear from the soil and from vegetation. After Monument Protection Comity database (kindly provided by A. Mnatsakanyan) khachkars of 13-16 century and one gravestone of 16-17 century are in the cemetery.

The pedestals of khatchkars correspond to big stony blocks with notches on the summit to place the "foot" of the khatchkars. These pedestals are overbalanced, overturned and broken (figure 10). The analysis of the modalities of their deformation suggests rather a seismic impact than destruction of human origin. One pedestal has two feet places (one of them on the flank) which are absurd if we don't suggest the destruction of the first khatchkar after its overbalance (A, figure 10).

On figure 10 (B) the person shows the site from where a fragment of the pedestal broken du to violent impulsion (C). The new surface was not covered totally with lichens yet, that suggests a phenomenon of relatively young age. Comparable destruction was noticed during the seism of Spitak in 1988.

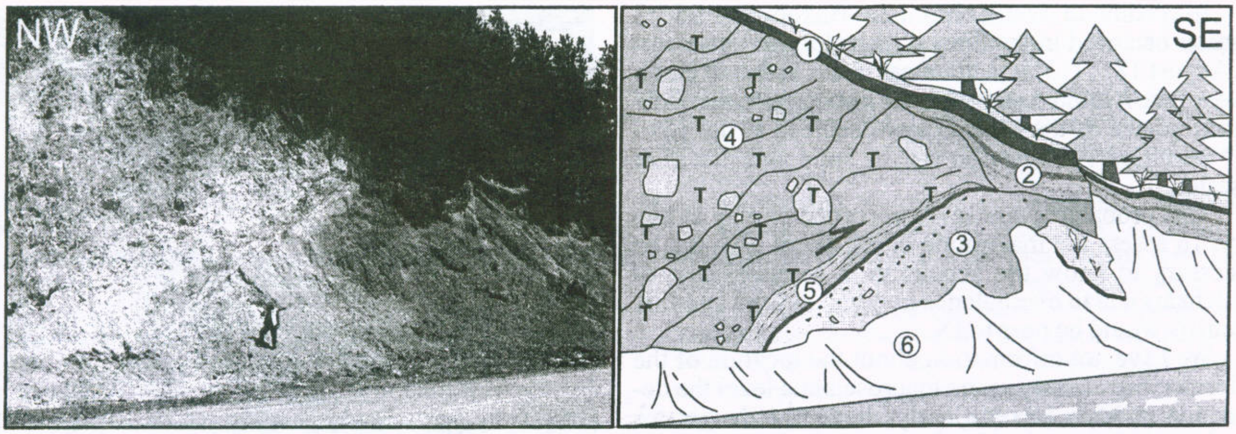

Figure 8: Reverse fault outcrop near the Lermontovo village. 1- modern soil, 2 – well stratified colluviums of send and gravels, 3- non stratified fin sand and clayey sand, angular fragments of unit 4 (predominantly of 2-5cm, rarely of >20cm size) embedded in a send matrix abundant near the fault plan and absent far, 4 – andesites and its piroclastes, 5- fault shear zone, 6- recent colluviums.

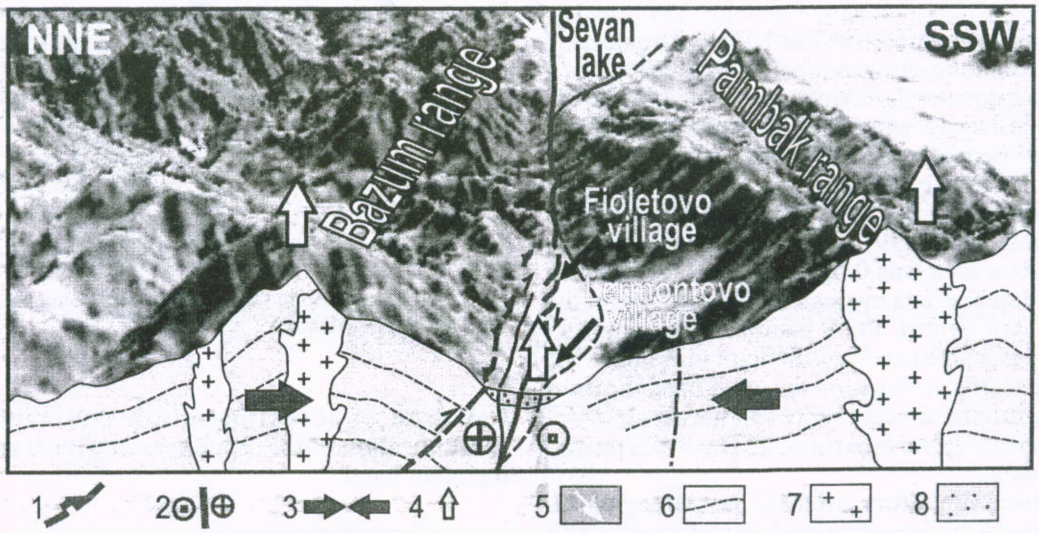

Figure 9: Schematic cross sections throw Tandzut river upstream area (near the Lermontovo village). 1- Reverse fault (with unclear activity), 2- active dextral strike-slip fault, 3- Compression axes, 4- local uplift, 5- arrows indicating fault zone, 6- Upper Cretaceous and Paleogene formations, 7- intrusive rocks, 8-Quaternary formation.

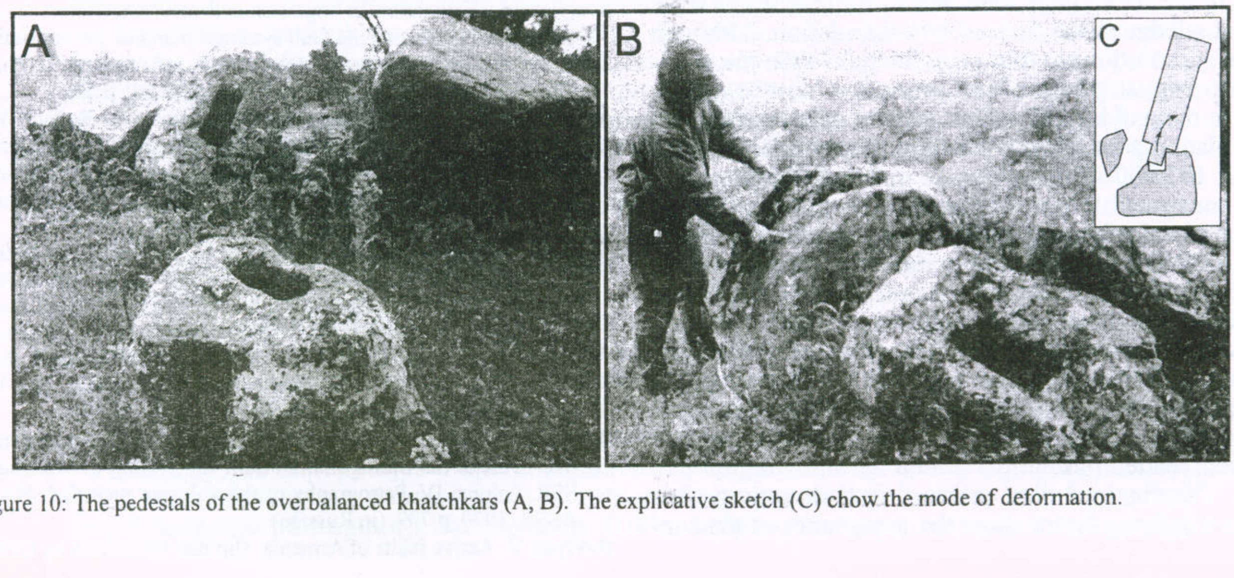

Figure 10: The pedestals of the overbalanced khatchkars (A, B). The explicative sketch (C) chow the mode of deformation.

According to Avetik chronicle (Hakobyan, 1956) a disaster occurred in the Gharakilisa (former Vanadzor) on August 18, 1713. It is not clear if this is due to earthquake; here it is interesting that the last burial in the abandoned village of the Mets Bager occurred in the 16th - 17th centuries. An abandon can be supposed just after disaster.

This probable event is not recorded clearly in history. To assess the magnitude of the event it would be necessary to know the acceleration to make take of khatchkars and to overbalance pedestals. Anyway MSK intensity would be near to IX.

We have not information about the location of the epicenter, but already in the macroseismic level the destruction in Mets Baker clearly shows the danger for Vandzor city situated in the depression.

Conclusion

Active faults which limit and cross (figure 11) the Vanadzor depression area present evidence of high hazard level.

According to the effective Earthquake Engineering Code of the Republic of Armenia (2006) the area has a deterministic estimate of maximum PGA value of 0.4 g. The new code has an advantage because it considers the fault as a seismic zone and allows multiplying the value with 1.2, thus we will have acceleration of 0.48 (it is a law in force). On the other hand in 1999 (Seismic Hazard Assessment, 1999) the estimated acceleration for the Vanadzor area was 0.6g. Avagyan (2001) based on paleo-earthquake data evaluated PGA >0.58g for the same area. These entire PGA estimates become secondary because in one hand it is difficult to estimate the PGA in fault nearby area and on the other hand the most important hazard for our case represent the capability of the fault to generate a surface rupture. The last is proven by obtained data.

The elapsed time (time after the last strong earthquakes) on the Arpi-Vanadzor and Vanadzor-Artanish segments is near to the respective estimate of earthquake recurrence interval (Avagyan, 2001; Karakhanyan et al., 2004), which means that the strain accumulation approach to critical level !

There are multitude city as San-Francisco, Wellington (USA), Izmit (Turkey), Tabriz (Iran) etc. situated in the active fault zone. It's a problem of low level of knowledge at the time of city foundation. Although there are solutions to minimize the risk level: the maximum permissible hazard level estimation must be equivalent to the real hazard, which is not a case in urbanization planning for Vanadzor area with total population of about 183,000. The fault trace must be considered as non constructible zone and respective architectural solution must be found (garden construction for example).

Risk level is high taking into account the seismic potential, interrelated natural (landslides, rock falls, liquefaction and subsidence), technologic or anthropogenic hazards (related to large chemical plant, synthetic fiber factory and thermal power plant) in the densely populated area. The well understanding of the hazard characteristics of faults is the first and important stage to prevent related risk.

The obtained data concerning fault activity as a main triggering factor show the importance of the continuation of investigation in one hand and the sensibilization of the republican and local authority on the other hand.

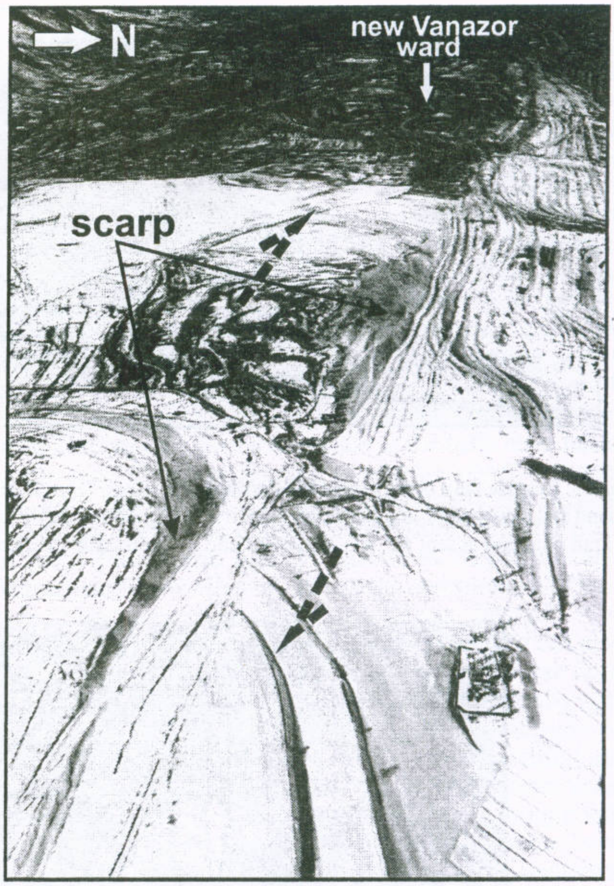

Figure 11. Fault scarp in the Vanadzor depression and the new city ward on its uplifted block.

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Reviewer A.S. Karakhanian

ԱԿՏԻՎ ԽԶՎԱԾՔՆԵՐԸ ԵՎ ԴՐԱՆՑ ՀԵՏ ԿԱՊՎԱԾ ՍԵՅՍՄԻԿ ՎՏԱՆԳԸ ՎԱՆԱՁՈՐԻ ԻՋՈՒՅԹՈՒՄ

Ա.Վ. Ավագյան

Ամփոփում

Վանաձորի շրջանում Փամբակ-Սևան-Սյունիք ակտիվ խզվածքի երկու սեգմենտները (Արփի-Վանաձոր և Վանաձոր-Արտանիշ) վերադրվում են ձևավորելով մոտավորապես 3կմ լայնքով և 16կմ երկարությամբ նշաձև իջույթ: Նրա արևմտյան մասը զբաղեցնում է Հայաստանի Հանրապետության երրորդ քաղաք՝ Վանաձորը: Իջույթի տարածքում խզումը ճյուղավորվում է սեգմենտերի, որոնք ունեն տարբեր ակտիվության աստիճան: Ընդհանուր առմամբ նրանք ներկայացնում են բարձր սեյսմիկ վտանգ և դրա հետ կապված ռիսկ: Ռիսկի կանխարգելման առաջին և կարևոր փուլը դա ակտիվ խզվածքների վտանգավորության բնութագրիչների ուսումնասիրությունն ու գնահատումն է:

Կարևոր է առավելագույն թույլատրելի վտանգի և իրական վտանգի համարժեքությունը, որը չի համապատասխանում Վանաձոր քաղաքի ուրբանիզացման պլանի հետ: Բնականաբար վտանգի մասին գիտելիքները զարգանում են և այն նույն մակարդակին չէ եղել Վանաձոր քաղաքի կայացման ժամանակ: Ժամանակակից տվյալները պետք է հաշվի առնվեն քաղաքի նոր պլանավորման ժամանակ: Ռիսկի աստիճանը բարձր է, հաշվի առնելով խիտ բնակեցված տարածքում սեյսմիկ պոտենցիալը, տեխնոլոգիական և անտրոպոգեն վտանգների հետ նրա փոխկապվածությունը:

Վանաձորի իջույթի շրջանում իրականացված պալեոսեյսմալոգիական աշխատանքները վեր հանեցին բազմաթիվ նեոտեկտոնական դեֆորմացիաներ ներկայացված պալեոտոպոգրաֆիայի տեղաշարժերով (հորիզոնական ուղղությամբ հասնում է մոտ 1.8կմ -ի)՝ ձևավորելով ձևատեկտոնական հորինվածքներ (սկարպեր, մերձ խզումային թմբեր և իջույթներ, տեղաշարժված և լքված հովիտներ և այլն): Երկրաբանական ֆորմացիաների ուսումնասիրությունը տարբեր մերկացումներում ցույց տվեցին ժամանակակից (Վերին Պլեյստոցեն-Հոլոցեն հասակի) ակտիվացումներ, ընդ որում իջույթի սահմաններում:

Հայտնի չեն գործիքային և պատմական ուժեղ երկրաշարժեր, որոնց էպիկենտրոնները լինեն ուսումնասիրվող տարածքում: Դա մասամբ բացատրվում է ուժեղ երկրաշարժերի կրկնելիության ինտերվալի մեծությամբ: Ուժեղ երկրաշարժերից ավերված գյուղերի և

հուշարձանների մասին վկայությունները մասամբ կապված են 1828 թվականի (էպիկենտրոնը գտնվում է մոտ 18կմ ավելի հարավ) և հնարավոր անհայտ երկրաշարժների հետ: Նախնական հնասեյսմալոգիական ուսումնասիրությունները Վերին Բակերում, որը գտնվում է իջույթի հյուսիս արևելյան սահմանի մոտ, ցույց տվեցին ավերվածությունների հնարավոր սեյսմիկ բնույթը: Այդ իրադարձության (համապատասխանում է մոտավորապես IX ինտենսիվությանը) էպիկենտրոնը հայտնի չէ, սակայն արդեն այդ փաստը վկայում է հարևան քաղաքին սպառնող ռիսկի բարձր մակարդակի մասին:

Ստացված պալեոսեյսմալոգիական տվյալները ցույց տվեցին մեկ ուժեղ պալեոերկրաշարժ ($Mw \geq 7.2$), որի էպիկենտրոնային շրջանը ներառում է առնվազն Վանաձորի իջույթի մի մասը: Երկու սեգմենտների միացման տարածքում նման ուժի երկրաշարժը ցույց է տալիս, որ սեյսմիկ մակերեսային խզվածքը տարածվել է երկու սեգմենտներով և Վանաձորի իջույթը չի հանդիսացել խոչընդոտ: Ստացված տվյալները ապացուցում են սեյսմածին մակերեսային խզվածքավորման հնարավորությունը իջույթի տարածքում, որը երկրորդական է դարձնում գրունտների առավելագույն արագացումների հաշվարկումը հնարավոր խզման սկարպի երկայնքով. քանի որ խզման գիծը համարվում է կառուցապատման համար ոչ պիտանի տարածք:

Աշխարհում Վանաձորը միակ քաղաքը չէ, որը գտնվում է խզման զոնայում: Օրինակ՝ Սան-Ֆրանցիսկոն, Վելինգտոնը ԱՄՆ-ում, Իզմիտը Թուրքիայում, Թավրիզը Իրանում այդպիսի քաղաքներ են: Գոյություն ունեն զանազան ճարտարապետական լուծումներ արդեն կառուցված քաղաքում ռիսկի նվազեցման համար, որը ճարտարապետների խնդիրն է:

Ստացված արդյունքները ցույց են տալիս ուսումնասիրությունների շարունակականության, հանրապետական և տեղական իշխանությունների ուշադրության անհրաժեշտությունը:

АКТИВНЫЕ РАЗЛОМЫ И СЕЙСМИЧЕСКАЯ ОПАСНОСТЬ В ВАНАДЗОРСКОЙ ДЕПРЕССИИ

А.В. Авагян

Резюме

В районе Ванадзорской впадины два сегмента Памбак-Севан-Сюникского активного разлома (Арпи-Ванадзорский и Ванадзор-Артанишский) накладываются друг на друга, формируя миндалевидную впадину шириной около 3*км* и длиной 16*км*. На западе этой впадины находится третий по величине город Армении – Ванадзор. Активные разломы в пределах впадины ответвляются на различные сегменты с разными степенями активности. В целом они представляют высокий уровень опасности и риска. Изучение характеристики опасности этих разломов является первой и важной стадией снижения риска. Другим важным аспектом является эквивалентность максимально допускаемой опасности уровню реальной опасности. Естественно, познание опасности развивается со временем, и оно не было на одном и том же уровне при становлении города Ванадзора. Современные данные должны быть учтены при составлении новой планировки развития города. Уровень риска высокий, принимая во внимание установленный сейсмический потенциал вкупе с технологическими и антропогенными опасностями в плотно населенной области. Палеосейсмологические исследования в районе Ванадзорской депрессии и прилегающих участков показали многочисленные неотектонические деформации, представленные смещениями в палеотопографии (горизонтально достигающие 1.8*км*) и образованием морфотектонических форм (скарпы, приразломные гребни и впадины, смещенные и мертвые долины, пулапарт басейны и т.д.). Исследование геологических формаций на различных обнажениях показало современную (верхний плейстоцен - голоцен) активизацию в границах самой депрессии. Для исследуемого района неизвестны сильные инструментальные и исторические события с эпицентром в районе депрессии. Это отчасти объясняется значительным интервалом повторяемости сильных событий. Свидетельства о разрушении сел, церквей и других памятников отчасти связаны с землетрясением 1828г. (с эпицентром около 18*км* южнее депрессии), а в основном неизвестны. Предварительные археосейсмологические исследования показали возможность сейсмического разрушения памятников местности Верин Бакер, находящейся на границе депрессии. Эпицентр этого возможного землетрясения не известен, но уже сам факт разрушений (соответствующих примерно IX-балльной интенсивности) наглядно показывает степень опасности для соседнего города. Получены данные об одном сейсмическом палео-событии с $Mw \geq 7.2$ с эпицентральной зоной,

включающей как минимум часть депрессии. Такое событие на стыке двух сегментов указывает, что Ванадзорская депрессия не была барьером для распространения сейсмогенного разрыва с одного сегмента на другой. Таким образом была доказана возможность поверхностного разрыва в пределах депрессии, в результате чего становится второстепенным расчет акселераций грунта вдоль возможного сейсмического разрыва, так как в градостроительном аспекте линии разломов являются непригодными для строительства.

Ванадзор далеко не единственный город, находящийся в зоне активного разлома (Сан-Франциско, Велингтон в США, Измит в Турции, Табриз в Иране и т.д.). Существуют различные архитектурные решения для снижения риска в уже построенных городах, и это задача для архитекторов.

Представленные данные по активности разлома свидетельствуют о важности продолжения исследований и привлечения внимания к этой проблеме со стороны местных и центральных государственных органов.