RECENT STRIKE-SLIP DEFORMATION OF THE NORTHERN TIEN SHAN M.M. BUSLOV . [ET AL.] pdf

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The paper presents a geodynamic interpretation of the deep structure and active tectonics of the northern Tien Shan, with particular emphasis on strike-slip motions, which produced a pull-apart in.

Gerhard Jentzsch Accepted Manuscript Title: S 09 DOI: GEOD To appear in: Journal of Geodynamics Please cite this article as: As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain. In the first step a composite seismic catalogue for the northern Tien Shan region was created, which contains about 20, events and is representative for strong earthquakes for the period back to the year For the an period of instrumental observation the catalogue contains data for earthquakes with a body wave magnitude larger than 4. For smaller events with magnitudes up to 2. M Due to the different magnitudes used in several catalogues a magnitude conversion was necessary. Event density maps were created to rate the seismicity in the region and to identify seismic sources. Subsurface fault geometries were constructed using tectonic model which uses fault parallel material flow and is constrained by GPS data. The fault geometry should improve the estimation of the expected seismic sources from seismic density maps. Annual seismicity distribution maps suggest different processes as the cause for the seismic events. Apart from tectonics, also fluids play a major part in triggering of the earthquakes. Beneath the Issyk-Kul basin the absence of strong seismic activity suggest aseismic sliding at the flat ramp in a ductile crust part and low deformation within the stable Issyk-Kul micro continent which underthrust the pt northern ranges of Tien Shan. First results suggest a new partition of the region in tectonic units, whose bounding faults are responsible for most of the seismic activity. Introduction During the last years Almaty was destroyed several times by strong earthquakes. The city is located on a large active fault zone of the northern Tien Shan. This fault called Almaty-Fault is covered by mezozoic and cainozoic sediments and does not crop out at the surface but its activity is shown by the high seismicity in the region. Located on the northern range of Zailijsky Alatau the northernmost ridge of Tien Shan Almaty is also endangered by debris flows which can be triggered by weaker earthquakes. With regard to the population of more than one million people the quantification of the seismic hazard has to be improved. The objective of the project is to improve the existing hazard maps and to create an up- to-date geodynamic model of the region. For our research we use data from different origins. In this work parts of the seismic hazard assessment are presented. Investigation area, geodynamic and geological setting The area of interest is located in Central Asia in northern Tien Shan and encompasses the two northernmost ridges of the mountain Zailijsky Alatau and Kungej Alatau and parts of sediments basins - the Ili basin and the Issyk-Kul basin. The north to south extension of the research area is nearly km and east to west km. M ed pt ce Ac Fig. General overview of the investigated area. Yellow circles are significant earthquakes in the region. Some focal mechanisms are given for strong earthquakes. The present day structure of northern Tien Shan consists of roughly E-W oriented ranges separated by parallel sediment basins. Ranges and basins are separated by big thrust faults. Northern Tien Shan ranges consist of metamorphic rocks but also of intrusive and volcanic formations. Sediment thickness reaches up to 4. The geodynamic situation in this region is controlled by the ongoing collision of India and Eurasia. The current geodynamic situation is given by the underthrusting of the Tien Shan from Page 2 of 15 south-east by the stable Tarim block, whereas Pamir is working as an indenter from the south and south-west. The observed deformations are actually discussed as a result of the rotational behaviour of the stable Issyk-Kul micro-continent and the development of strike slip faults BUSLOV et al. The earthquake focal mechanisms from Harvard CMT Earthquake Catalogue show thrust faults with strike slip components which also point to the ip regional compression regime with escape tectonics. The regional stress map is exclusively based on focal mechanism solutions. The predominant strike direction of the compression axis is approximately N-S,

almost perpendicular to the east-west strike direction of the mountain range MAKAROV et al. Smaller earthquakes cannot be allocated to certain tectonic structures and us seem to occur everywhere at shallow depths. Events with magnitudes smaller then 3. Seismic hazard assessment an Seismic hazard requires the knowledge of possible epicentre locations, occurrence and strength. The process of seismic hazard assessment consists usually of four steps. The first step is the characterization of the seismic sources. The second step is the estimation of earthquake recurrence from seismic catalogues. The third step is the estimation of ground motion attenuation from macro seismic data e. M The last step is finally the calculation of probability of the exceedance for events of certain magnitudes for a certain time period. Seismic catalogues Regarding the central issues of the hazard assessment, in the first step the composite seismic catalogue for the northern Tien Shan region was created, which goes back to the time until A. For the period of instrumental observation the catalogue contains data for earthquakes with a magnitude pt bigger than 4. The instrumental ce data for the last two years can be updated continuously from the KNDC online catalogue. In several catalogues different magnitudes were used to characterize the earthquake strength. After the composition of these catalogues three magnitude classes were available. The body wave magnitude mb, which was used preliminary in the NEIC catalogue, the body wave magnitude mpv from KNDC catalogue, which is derived from the vertical Ac component and for their estimation a local calibration curve was used. As well as the energy class K which represents the logarithm of the seismic energy at the distance of 10 km from epicentre and is mostly used for the classification of the earthquake strength in Russian catalogues. For homogenisation of the catalogue it is necessary to convert different magnitudes to one reference magnitude, which will be used as a standard for the seismic hazard assessment. Of course there are empirical relations from former studies of the region, but it is always advisable to convert the magnitudes from the used dataset, if possible. The dataset contains several magnitudes for events in some time slices. Some periods with different magnitudes are overlap so that for the same event two or even all three magnitudes are available. Such events were filtered from the catalogue. This dataset with filtered magnitudes was split into training and test datasets. Within the training data the conversion of the magnitudes by linear regression was arranged Fig. Thereafter the Page 3 of 15 estimated conversion parameters were applied for the test dataset. Due to the fact that for the test data magnitudes from primary estimation were available it is possible to prove the quality of the conversion by testing the residuals between estimated and calculated magnitudes. Conversion of the magnitudes energy class K to mpv by linear regression. The conversion is of different quality. The conversion of mpv to energy class K can be well done with linear ed regression. The standard deviation is 0. Conversion from mb to mpv is linear only in a range between magnitudes 2. Residuals from calculated magnitudes and observed magnitudes are shown in Fig 3. For bigger and smaller magnitudes big standard deviations are needed to process them with linear pt regression. The results are summarized in Tab. Residuals from class to mpv conversion. Page 4 of 15 Tab. Seismic density maps cr In the first step of the seismic source identification, seismic density maps were created by using kernel density function DUONG et al. Kernel density provides different density estimators. The general form of a kernel estimator is: For this analysis we used the quadratic kernel function: All seismic events were assumed as point sources in the first approximation. The optimal bandwidth was calculated automatically with the least squares method from the dataset. In simple terms the analysis process can be describe as follows: A smoothly curved surface is fitted over each point. The surface pt value is highest at the location of the point and diminishes with increasing distance from the point, reaching zero at the search radius distance from the point. Only a circular neighbourhood is possible. Page 5 of 15 The density at each output raster cell is calculated by adding the values of all the kernel surfaces where they overlay the raster cell centre. Increasing the search radius will not greatly change the calculated density values. Although more points will fall inside the larger neighbourhood, this number will be divided by a larger area when calculating density. The main effect of a larger radius is that density is calculated considering a larger number of points, which can be further away from the raster cell. This results in a more generalized output raster. The idea of this analysis is that near to the active faults the number of seismic events per area should be higher then in their

surroundings. After the calculation of the seismic density the faults known from geologic mapping were overlaid with the density maps Fig. This period was chosen because the instrumental observation shows about equal quality and ip number of events. These annual maps are very helpful to understand the continuity of the activity from earthquake sources and their origin. So, the smooth density gradients with slowly changing shapes through the years point to zones caused by continuously ongoing tectonic processes active faults. Sudden swarms, like in cr Fig. Sequence of annual seismic density maps of four years from until Shape of this activity zones around Issyk-Kul and northern ridges change only slightly from year to year.

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Mainly working with GIS and Remote Sensing, structural analysis microtectonics and Radon-gas geochemistry, related to faulting. Investigation of contaminated sites in the framework of the surveillance of the Territory. International field Intercomparison campaigns in soil gas radon mapping Czech Republic, Spain, Serbia. Characterisation of radium contaminated sites in the framework of the definition of the Anthropogenic radon risk areas in Belgium. Various international intercomparison campaigns of radon field mapping soil-gas, water, air , several field surveys for environmental radioactivity. Relations between radon emanation and brittle structures joints and faults. In cooperation with Prof. Sintubin University of Leuven, Belgium and Dr. June and June Study of the kinematic evolution of large intra-continental multi-stage strike slip sutures: Paleostress, paleostrain and kinematic study of the Shapshal fault zone. In cooperation with Dr. Lake Teletskoye Basin, Russian Altai: June-July , , and Study of the brittle deformation related to the extensional graben formation: Fault kinematics, micro-structural analysis, soil-gas analysis for Radon concentration and exhalation related to fault zones. July and July Study of the brittle deformation related to basin development. Study of the Chon-Kemin active fault zone by remote-sensing, morphology and field geology. Supervision and guidance of Belgian and Russian under-graduate students during a summer field-school on active tectonics in Altai and Tien Shan. Study of the Cenozoic evolution of different continental fault-bounded basins in the Altai-Sayan region. Timing, kinematic history and brittle micro-tectonics of the Ubsu-Nuur and West-Tuvinian basin. Tunka depression, south Siberia: Study of the relation between Cenozoic volcanism and variation of the regional stress field. Lake Baikal, August, Supervision and guidance of field summer school for under-graduate students from the VUB of Brussels. Study of the rift-related brittle deformation. Lake Teletskoye, , July-August, Study of the joint- and fault pattern delimiting the Teletsk basin, by remote-sensing, brittle structural field geology and sampling for geochronology. Publications Books and book chapters Self-sealing of fractures in argillaceous formations in the context of geological disposal of radioactive waste. Physical and geological environment of Lake Teletskoye. Edited by Selegei, V. Koninklijk museum voor Midden-Afrika Tervuren. Continenten splijten en diepe troggen ontstaan, in Afrika Museum tervuren: Van den Audenaerde, pp. Mapping uranium concentration in soil: Belgian experience towards a European map. Journal of Environmental Radioactivity , pp â€" Estimating the terrestrial gamma dose rate by decomposition of the ambient dose equivalent rate. Journal of Environmental Radioactivity , pp High radon areas in the Walloon region of Belgium. Radiation Protection Dosimetry , pp Homogenity of geological units with respect to the radon risk in the Walloon region of Belgium. Journal of Environmental Radioactivity , pp. Development of an indoor radon risk map of the Walloon region of Belgium, integrating geological information. Environ Earth Sci 62, Estimating lung cancer risk due to radon exposure in the radon-prone areas of Belgium. The application of radon measurements in the radon action plan in Belgium. Multi-method chronometry of the Teletskoye graben and its basement, Siberian Altai mountains: New insights on its thermo-tectonic evolution. Geological Society Special Publication , pp. Statistical analysis of indoor radon data for the Walloon region Belgium. Radiation Effects and Defects in Solids , pp. Radiation Measurements 43, SCI 1,05 Dehandschutter, B. Brittle fractures and ductile shear bands in argillaceous sediments: Journal of Structural Geology 27, , Volumetric matrix strains related to intraformational faulting in argillaceous sediments. Journal of the Geological Society, London , , Applied Clay Science 26, , Microfabric of fractured Boom Clay at depth: Recent strike-slip deformation of the Northern Tien Shan. Geological Society Special Publication , London, pp. Water, Air, and Soil Pollution , , Aardkundige Mededelingen 12, , Tectonophysics , , Russian Geology and Geophysics 43 2 , , Kinematic evolution of the Teletsk graben Russian Altai. The Teletsk Tectonic Depression Altai: Abstracts of Posters and Oral presentations Dehandschutter B. Radon in

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We study crustal deformation in the northern Tien Shan as recorded in strain rates derived from earthquake and GPS data. Geodetic strain rates indicate general shortening along the N-S component and agree with Quaternary fault slip rates and with the strain field obtained from earthquake mechanisms, all being signature of overall north-south contraction in the region.

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