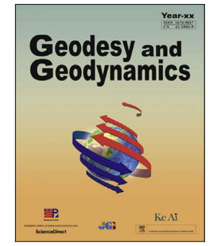
Ke Ai
ADVANCING RESEARCH
EVOLVING SCIENCE

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.keaipublishing.com/en/journals/geog;
http://www.jgg09.com/jweb_ddcl_en/EN/volumn/home.shtml



Recent geodynamics of major strike-slip zones

Trifonov Vladimir G. [a,*], *Korzhenkov Andrey M.* [b], *Omar Khaled M.* [b]

[a] *Geological Institute, Russian Academy of Sciences, Moscow, Russia*
[b] *Institute of Physics of the Earth, Russian Academy of Sciences, Moscow, Russia*

ARTICLE INFO

Article history:
Received 16 May 2015
Accepted 4 July 2015
Available online 6 November 2015

Keywords:
Active strike-slip faults
Historical seismicity
Paleoseismicity
Temporal variations of focal mechanisms of earthquakes
Rates of accumulation of strike-slip deformation

ABSTRACT

The subject of this study is strike-slip fault zones, where temporal variations of accumulation in strike-slip deformation complicate the standard process of deformation accumulation and release during strong earthquakes. These temporal variations are expressed in the El Ghab segment of the Dead Sea Transform zone (DST, Eastern Mediterranean) and in the Talas-Fergana fault zone (Central Asia). According to Global Positioning System (GPS) data, the strike-slip deformations within these zones are not now accumulating or are accumulating at a rate that is significantly less than their average rate during the Holocene and Quaternary or the Pliocene–Quaternary. Simultaneously, weak transverse shortening has been measured in both zones by GPS. In both of these zones, strong earthquakes have not registered within the XX century, yet epochs of intensified seismicity (strong earthquakes) took place throughout history. In the southern and central parts of the El Ghab zone, there is evidence of 30 strong historical earthquakes of $Ms \geq 5.7$; however, no instrumental earthquakes of $Ms \geq 5$ have been identified. The temporal distribution of seismic energy released by these earthquakes demonstrates a 350 ± 50-year cycle. Values for the seismic energies released during the peak phases of these cycles are approximated by a sinusoid that suggests the possibility of a ≥1800-year cycle ("hyper-cycle"), which began around the 3rd century, reached its maximum in the 12th century, and has continued until now. A combination of geological, archaeoseismological, and geodetic data show that the rate of sinistral strike-slip deformation varied in the fault zone, probably in conformity with the variation of seismicity during the "hyper-cycle." In the Talas-Fergana fault zone, trenching and ^{14}C dating that was correlated with right lateral offsets, gave a possible preliminary estimate of the average rates of the Late Holocene strike slip of about 10 mm per year, with a decrease in the SE direction to 4 mm–4.5 mm per year. These studies also showed that the slip in the Talas-Fergana fault zone was realized mainly during strong earthquakes. New trenching and ^{14}C dating of paleoearthquake records identified the epoch of seismicity intensification dating to the XIV–XVII centuries. These paleoearthquakes could produce a total dextral slip at several meters. Therefore, consideration of these epochs was necessary to determine a calculated average slip rate during the Late Holocene.

The main shock and the strongest aftershocks of the Altai earthquake of September 27, 2003, with $Ms = 7.0$ demonstrated a strike-slip focal mechanism with an NW-trending

* *Corresponding author*. Tel.: +7 916 5404052; fax: +7 495 9510443.
E-mail address: trifonov@ginras.ru (Trifonov V.G.).
Peer review under responsibility of Institute of Seismology, China Earthquake Administration.

ELSEVIER Production and Hosting by Elsevier on behalf of KeAi

http://dx.doi.org/10.1016/j.geog.2015.06.003

plane of the right lateral slip. An approximately 65 km-long NW-trending seismic rupture with a right lateral slip of up to 2 m, formed during the earthquake. The aftershock activity significantly decreased in 2004–2005 when reverse and rarer normal focal mechanisms became dominant. In the Palmyrides and the southern Aleppo block (NW Syria), strong earthquakes in 1994 (Mw = 5.3) and 1996 (Mw = 5.5) had strike-slip focal mechanisms, while only weak (magnitudes 1.1 to 3.3) earthquakes occurred in 2009–2011; the overwhelming majority of these weak earthquakes had normal and reverse mechanisms.

In all of the cases mentioned above, strike-slip deformation was expressed only or mainly during strong earthquakes. At other times, the rate of its accumulation was small and the dominant stress conditions led to transverse shortening, rarely resulting in local lengthening of the tectonic zone. These variations are caused by the tectonic peculiarities of these zones. The sinistral component of the deformation is related to the shift of the Arabian Plate relative to the African one, but also the transverse component is related to the continental slope and is expressed by the Coastal range shortening that exists in the El Ghab segment zone. There is not only a dextral deformation component, but also a transverse component, expressed by shortening of the Fergana and Talas ranges existing in the Talas-Fergana fault zone. In both zones, the shortening component became appreciable or dominant when the strike-slip deformation rate decreased. Similar, but more local, relationships were expressed in the epicentral area of the 2003 Altai earthquake and in the Western Palmyrides.

1. Introduction

Recent geodynamics of major strike-slip faults in orogenic regions can be studied using three groups of methods. The first group consists of geological and geomorphological studies of young strike-slip offsets and the associated deformation of topographic features, geological bodies, and archaeological objects. The second group focuses on the identification and parameterization of instrumental and historical earthquakes, as well as expressions of archaeoseismicity and paleoseismicity. Estimation of offset ages is the most difficult part of determining the average rate of Late Quaternary displacement on strike-slip faults. The same difficulty exists for the estimation of past earthquake dates if instrumental and historical data are absent. In this situation, we determine the age of objects that were deformed during the earthquake or that were formed as the result of the earthquake, or later. These objects provide the upper and lower limits for the earthquake age. An attempt to estimate the age of an event by dating of the colluvial wedge is often erroneous, because the analyzed material of the wedge (for example, the lower layer of the displaced soil or the earlier archaeological artifacts) can be older than the wedge itself. A wide set of methods must be used for this type of dating and the resultant precision is not usually better than several decades. A combination of the methods (for example, use of both the historical chronicles as well as the archaeoseismology and paleoseismology data) offers the most reliable estimation of pre-instrumental earthquake parameters.

The third group combines the results of the repeated geodetic, especially Global Positioning System (GPS), observations. There are three movements regimes on active faults. They are: (1) creep, accompanied by weak earthquakes; (2) a combination of creep and rare strong earthquakes; and (3) displacements, only during rare strong earthquakes. Regimes (1) and (3) are rarely realized, while different variants of regime (2) have the most wide-spread usage. According to regime (2), elastic deformation is only partly released during creep time intervals and is gradually accumulated, leading from time to time (often periodically) to strong seismic releases of accumulated deformation resulting in significant displacement on the fault. If the GPS observations record the entire fault zone, they can register the total accumulated deformation that is expressed in the land surface and the results do not depend on whether the deformation is realized by immediate offset and permanent deformation or if it exists elastically for the time being.

If the deformation accumulates permanently, the rates of deformation, estimated using different methods, must be approximately the same, although they characterize different time intervals. The rate of the geological deformation is estimated by the average rate of the displacement on the fault during some time interval. The seismological estimate is a sum of the seismic displacements during the fixed time interval with corrections for the contributions of creep and weak earthquakes. The geodetic (GPS) estimate expresses the total accumulated deformation, but is related to the shortest time interval, usually not more than one decade, but can rarely be several decades.

The estimations of the lateral slip rates, obtained using different methods, are similar to those of major interplate strike-slip faults, such as the San Andreas Fault in California and the North Anatolian Fault in Turkey. This shows that strain release rates on those faults result in more or less permanent average slip rates. Molnar and Dayem [1] summed