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Outstanding Student Poster Contest

The 1911 Chon-Kemin (Mw 8.1) earthquake in the Tien-Shan region: preliminary investigation results by means of historical data

Galina Kulikova [1)], Frank Krüger [1)]

1) Institute of Earth and Environmental Sciences, University of Potsdam

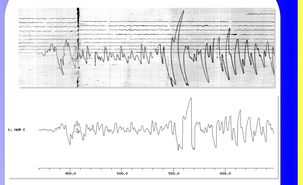
Contact: Galina.Kulikova@geo.uni-potsdam.de

Why Chon-Kemin earthquake?

- The **M8.1** Chon-Kemin earthquake occurred on the 3rd January 1911 and it has considerably **damaged Verniy (Almaty) city** which was just recovered after previous strong earthquakes (1887 and 1889).
- Deep **surface cracks** were observed in Verniy.

- It was **the strongest earthquake** ever recorded in the Tien-Shan region.
- The total length **of the Surface rupture** was **200 km**.
- Up to 10 m of vertical displacement on the surface
- Although the population of Almaty was very small in 1911, **many people were killed**

Working with historical data



Uncertain amplitude correction of the seimograms (bottom) compared to the real analog recording (top).

- The most serious difficulty is the **curvature correction** of historical recording
- The Curvature correction may bias the amplitude and period of some parts of the record.
- Sometimes instrument parameters such as **damping and period are missing**.
- The exact picking of arrival times is difficult due to the **lack of universal clock**
- However, **digitized data** remain a **reliable source of information**.

References:

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2. Cadek, O.: Studying earthquake ground motion in Prague from Wiechert seismograph records. Gerlands Beitr. Geophysik, 96, 1987, 438-447
3. Bogdanovich K.I., Kakke L.M., Korolkov B.Ya., Mushketov D.I., Earthquake in the northern regions of Tien_Shan. 1914 Geographical report committee
4. Peter Borman, IASPEI, New Manual of Seismological Observatory Practice, 2002
5. Schweitzer, J. (2009). HYPOSAT / HYPOMOD. In P. Bormann (Ed.), New Manual of Seismological Observatory Practice (NMSOP) (pp. 1-16). Potsdam: Deutsches GeoForschungsZentrum GFZ. doi:10.2312/GFZ.NMSOP_r1_PD_11.1.
6. Josep Batlló "A CATALOGUE OF OLD SPANISH SEISMOGRAPH".

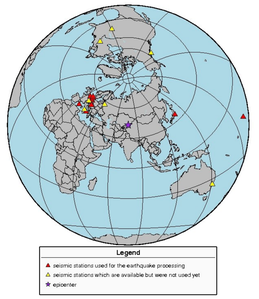
Acknowledgement:

We would like to express our gratitude to all the people who helped us to collect the historical seismograms and all the institutes which allowed us to access their archives. We sincerely thank: Dr Josep Batlló, Observatori de L'Ebre, Spain for significant help in the collection historical instruments characteristics; Dr. Susana Custódio, Centro de Geofísica da Universidade de Coimbra, Portugal; Dr. Ivo Allegretti PMF Geophysical Institute, UNI Zagreb; Group of Dr. Graziano Ferrari, INGV Rome; Prof. Dr. Luis Rivera, IPGS, Strasbourg University, France; Dr. James Dewey U.S. Geological Survey National Earthquake Information Center; Prof. Dr. Torsten Dahm, University of Hamburg; Dr. Rudolf Widmer-Schnidrig, Black Forest Observatory (BFO).

Introduction

Several strong destructive earthquakes occurred in the Tien-Shan region at the turn of the XIX. to the XX. centuries with magnitudes, which in two cases exceeded M8. Very strong **intracontinental earthquakes** with **thrust mechanism** are rare in the history of seismology. Therefore, geoscientists are strongly interested in the Tien-Shan region. This study is focused on the **investigation of the fault processes** of strong historical earthquakes. Here, the preliminary results for the **1911 Chon-Kemin** earthquake are presented.

Data

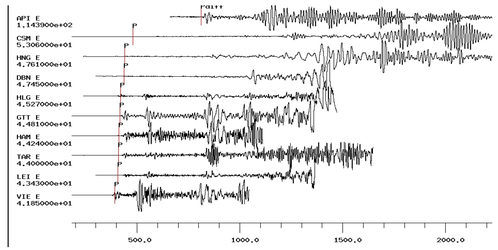


Seismic stations map for Chon-Kemin earthquake

- The data for Chon-Kemin earthquake were collected from **20 seismic stations** around the world
- The **historical seimograms** were taken from the different archives, **scanned** and then **digitized manually.**
- While working with historical seismic records one has to take into account all the aspects and **uncertainties** of **manual digitizing** and the **lack of instrument characteristics.**

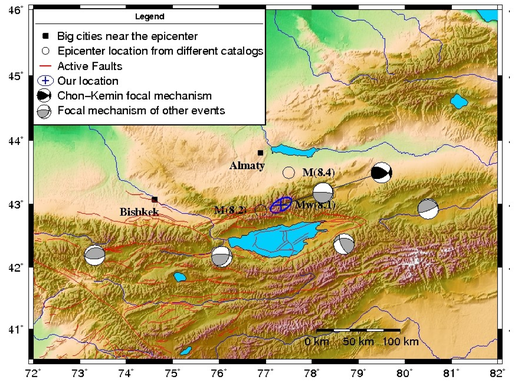
Earthquake relocation

- The earthquake was relocated using the program HYPOSAT based on the arrival time differences of **P and S wave onsets**.
- The relocated epicenter is 42.987°N and 77.3320°E. The solution is most stable for a depth between **20 and 25 km**.
- The moment magnitude and the **body wave magnitude** [Borman et.al.] were calculated to Mw =8.1 and **mB=7.2,** respectively



Example of digitized seismic waveforms for E components of 10 different stations aligned by distance, with theoretical P onset. These data were used for the relocation of Chon-Kemin earthquake.

Chon-Kemin earthquake epicenter location and fault map



Different locations avaliable for Chon-Kemin. The location determined in this study is marked in blue. The elipse shows 1-sigma standard deviation of the epicentral location.

Mechanism determination

- Full waveform synthetic seismograms were calculated with the reflectivity method for different test depths.
- The synthetics were rotated into the local station ZNE coordinate system and historic seismograph recordings were simulated with given values for damping and free period of the respective instrument.
- For each data record amplitude ratios were determined between P, PP, S and (down-weighted) SS and surface wave wavetrains.
- In a grid search procedure the simulated recordings were calculated with 10° spacing in strike, dip and rake angle and then compared to the data amplitude ratios (upper panel).

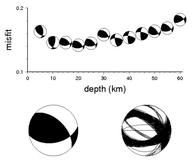


Figure 1a: Calculation of the focal mecahnism of Chon-Kemin earthquake

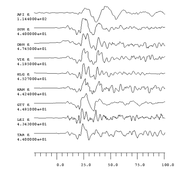


Figure 1b: Data of the Chon-Kemin earthquake aligned for P-phase for all the stations

Seismic Moment determination

- Full waveform synthetic seismograms were calculated and rotated into ZNE coordinate system
- Based on the values for damping and free period of the respective instrument the response was calculated and then applied to the synthetic seimograms
- The amplitude ratios between real seismograms and simulated ones were calculated
- The real moment is then obtained from the moment used for calculating synthetic seismograms by comparing the amplitudes

Station	Moment (dyn-cm)	Error	Mw
HAM	1.75E+028	±0.098	8.10
GTT	1.45E+028	±0.328	8.05
HNG	7.00E+027	±0.335	7.83
LEI	1.46E+028	±0.281	8.05
DBN	1.63E+028	±0.182	8.08
Moment	**1.57E+028**	**±0.222**	**8.07**

The vales of seismic moment for different seismic stations seem to be consistent, except for the HNG station (excluded), what can be explained by uncertain instrument information.

Discussion

The Chon-Kemin earthquake has **thrust mechanism** with a strike slip component (strike 80°, dip 50°, rake 50) in correspondence with the overall compressive regional stress characteristics.The dominant slip likely occurred in the upper crust (regional crustal thickness is about 50 km). The geological data from Arrowsmith et. al. show strongest **vertical surface displacement** on the most eastern part of the fault and a total length of about **200 km** with decrease of vertical displacement to the West.

Estimated from the P-waveforms the total source time duration is about 40 - 45 seconds, which, assuming a rupture speed of 90% of upper crustal shear wave velocity, results in about 120 km rupture length for unilateral rupture.

Data from the most distant eastern station (API, Samoa) indicate **an East -West propagating rupture,** due to the general higher frequency content observed for P (and PP, not shown) at European stations. However the data from this station can be affected by regional tectonics of the island and P-wave at API is Pdiff (114° distance). No no one-to-one **correspondence between geological** surface data and seismological data is observed.

Conclusion

- The epicenter of Chon-Kemin earthquake was relocated based on the **arrival time differences** of P and S waves onsets.
- The **mechanism of the earthquake was determined** based on the first set of data
- Data indicate **an East -West propagating rupture**
- The **seimic moment** of the earthquake was determined
- Additional data, which were recently obtained, are expected to give more information, and Chon-Kemin earthquake needs to be compared with later events from this region.