

ΣΕΙΣΜΟΛΟΓΙΑ.—Some Remarks on the Earthquake in Korinthos 1928, by Mr. H. Tanakadate.* Transmitted by Mr. Const. A. Ktenas.

In the general meeting on May 3rd 1928 of the Accademy of Athens, in which I had the honour to be present, Professor EGINITIS reported the results of the seismological study of the Earthquake station in Athens together with the researches of M^r. CRITIKOS about the disastrous shocks of Korinthos.

Now I have the honour to present this small and preliminary report about the desastrous earthquake. I visited the scene of the catastrophe with M^r PAPASTAMATIOU, assistant of the Mineralogical and Petrological Institute of the University in Athens, from 29th April to 1st May. This is only an impression got during my short stay in Korinthos. I am much obliged to Professor C. KTENAS for his kind suggests and helps for the following works.

Damages.— 1) Korinthos. The city is built up on the marine sand in its northern half, while the southern half on the tertiary sediments. The ground on which the city stands slopes slightly towards the sea. The large houses and buildings were in the Harbour Street on the shore sand deposits, and they are almost completely destructed by the shocks. The irregularity of the directions of the falling of the walls of the houses, shows that the city is located near the epicenter of the earthquake, so that the vibrations were rather undulatory. The main direction of the vibrations of the buildings, however, was in average NE-SW. One of the monuments in the Garden of the S. Paul Church is fallen towards West, while the other situated in front of the Church is displaced several centimeters to the SW direction. The fence wall of the Garden, which runs to NW direction is for most part fallen to NE and a little to SW. In the southern part of the city there are small houses of one store, they are comparatively little damaged.

The directions of fractures on the wall of houses, show that the shocks vibrated in the direction of NEE-SWW. Regarding the importance of construction of the buildings for earthquakes, there are several exemples to mention: At the NW part of the city, there is a new school near the

* Η. ΤΑΝΑΚΑΔΑΤΕ. — Παρατηρήσεις περί τοῦ σεισμοῦ τῆς Κορίνθου, 1928.

shore; it is a big and rigid building founded on sand bed. This building is only cracked on its wall, while the houses, East of this, are mostly destroyed, though they seemed to be strong and firm. The French Consulate at the corner of the Central Park of the city is one of the strongest buildings and it is only slightly damaged in spite of his two store height, while the houses around it were damaged very badly. Such difference of the destruction of houses depends upon naturally to the construction and the building materials.

The place Poseidonia at the Canal opening and the houses by the bridge on the Canal were also badly damaged. The people say that the main vibration of shocks was in the direction NEE to SWW.

2) Lutraki. The most of the part of the village is situated at the foot of a limestone hill, but the main street runs along the sea coast and on the shore sand. The houses in the principal streets were damaged completely, while the houses on the hillsides have escaped the catastrophe. We see here, therefore, that the alluvial soil is not favorable for the constructions of the antiseismic houses.

A large high building, «Palmyra Hotel», constructed partly on the limestone in the NW part of the village, is only slightly cracked, while the low houses near the hotel, though they are founded on the limestone, are broken down, for the buildings materials are not selected for the firm construction. From the cracks on the walls of some houses, it is sure that the main vibration of the shocks was SSE - NNW direction.

3) Kalamaki. The foundation of the village is sand underlaid by the neogene sediments. The village consists of 30 houses only, and they are completely damaged. This heavy disaster is caused not only by the unstable foundation of the village, but through the comparatively strong earthquakes, because such firm building as the railway station was also badly damaged, though it stands on the firm foundation. They say that the direction of the principal vibration was NW.

4) Isthmia. The foundation of the village is upper tertiary covered with thin alluvium in the part near the shore. The people say that the shocks came from NW and the movement was rather undulatory. The damage is very slight and only a few houses are cracked. In the opposite side of the Canal practically no disaster was given by the shocks.

5) Ancient Korinthos. The foundation is tertiary, the houses are cracked

very badly and the stone fences are broken down to a great deal. Even the new rigid building of the Excursion House of the American School for Classical Study has been very badly cracked, so that the people could not stay any more in it. Such heavy damage of this village depends not only upon the bad construction of the houses but upon the severity earthquakes. They say that the direction of vibration of the earthquakes on April 22nd was N-S, while that on the 29th was NEE to SWW.

6) Perijali, Assos, Brachati, Kokoni, etc. Some houses are cracked but there is no building which is completely damaged by the shocks. They say that the seismic vibration came from eastwards.

7) Bello, Neratza. They say that the villages of Bello and Neratza are very badly destructed by the earthquakes on 22nd as well as that of 29th April. It may be possible that Neratza stands on the unstable foundation of the shore sand, so that the shocks were very strong, but for the Bello my observation fails to give some conclusion.

8) Kiaton. The coastal part is built on the shore sand and only some houses are cracked on their wall very slightly and the tiles of them are fallen on the ground. They say that vibration of the earthquakes on 22nd was NNE-SSW and that of the shocks on 29th was SEE-NWW.

Cracks on the earth surface.—The cracks and fissures which took place on the ground by the earthquakes are not so many. (Fig. 1).

In the City of Korinthos, several cracks are seen in the shore near the S. Nicola Church, but they have no important meaning to the earthquake. To the west of the Palmyra Hotel of Lutraki, just at the shore, there are some fissures on the alluvium and parallel to the shore line. On the principal road between Lutraki and Korinthos along the coast, some fissures took place along or across the road. Among these fissures one is about 15 meters long and runs in the direction of N 70 W across the road. This is located by *Bukuwara* just at the southern termination of the village on the alluvial sand, but it seems to have some importance for the earthquake. In Kalamaki, minor fractures occurred on the shore just at the landing place of boats.

In Isthmia, small cracks occurred along the Canal side, just at the junction between the Canal wall and the mole, but they have no weight for the earthquake origins.

It will be noted here a fissure, found on the NE side of the Canal

and just at the highest part of the hill which the Canal cuts across. This is a small fissure but it is about 50 meters long and ends to the wall of the Canal; its direction is $N 70^{\circ} W$ and its continuation in the other side of the Canal, coincides with a large fault line. Among the fissures mentioned above, this seems to be most important to the cause of the earthquake.

Personal feeling of the earthquakes. — During my stay in Korinthos, I felt several earthquakes:

1) On April 29th, 11 h. 50 m. a. m. (after my watch). I felt a strong earthquake, when I was sitting on a chair in the Central Park of the City

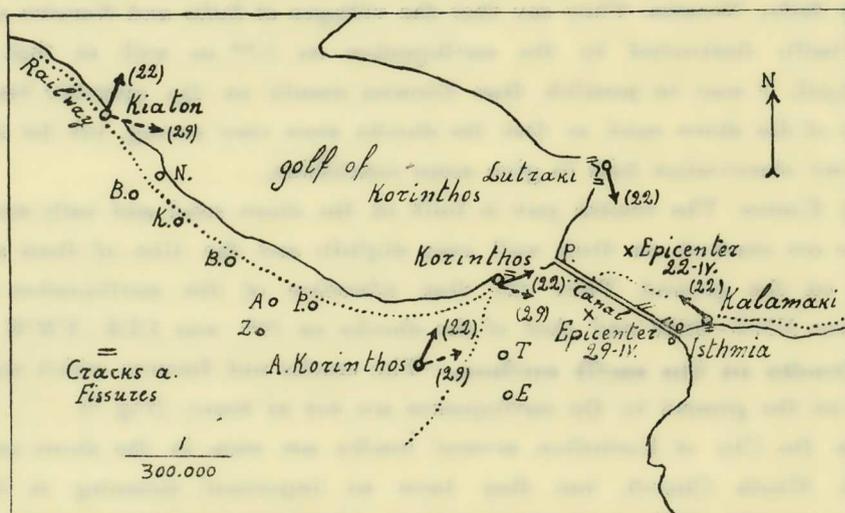


Fig. 1.

of Korinthos. At first an undulatory shock was felt from SEE, it increased by and by its magnitude. After 5 seconds the tiles were fallen from the damaged Houses, the shock continued some ten seconds. The movement was undulatory and very irregular, but the principal direction of the vibration was $S 55^{\circ} E$. By this earthquake some damages are caused in the villages such as Bello and Ancient Korinthos.

2) On April 30th, 6 h. 15 m. a. m. (after my watch), when I was in bed in a military house, just behind the city of Korinthos, I felt a slight shock which came from SW direction and continued some 5 seconds. The mean direction of the vibration was NE-SW.

3) On April 30th, 10 h. 25 m. a. m. (after my wath), I felt a shock, when

I was sitting on a chair in front of the house, which is situated by the eastern side of the Iron Bridge of the Canal. The trembling came from SE, it was rather an undulatory shock and continued some 5-6 seconds; the principal direction of the quakes was SE-NW.

4) On April 30th, 7 h. 15 m. p. m. (after my watch), a strong shock was felt by us, when we were walking on the hill (the highest part of the Canal region) just at NE edge of the Canal wall and about one kilometer SE from the bridge. The first shock came from SSE and the undulatory movements continued some 6 seconds. The main direction of the shocks was NNW - SSE.

5) On May 1st, 6 h. 11 m. a. m., when I was in bed on the military house, behind the City of Korinthos, a slight trembling came from SW direction and it continued about 5 seconds.

The Epicenters. — From the above descriptions: 1. the area most severely devastated by the earthquakes contains Korinthos, Lutraki and Kalamaki. On this area almost all houses standing on the plain (not on the rigid rocks) are damaged. 2. Such villages as Ancient Korinthos, Bello, Neratza, seem to be destructed next to the above area. 3. Perijali Assos, Brachati, Kokoni, Kiaton etc. are slightly damaged.

Judging from the principal direction of the shocks and that of the falling down the houses and house walls, the epicenter of the earthquakes on 22nd April may lay in the severely devastated area, 1. at the NE side of the Canal. As to the epicenter of the earthquake on 29th April, it seems to lay SE from Korinthos (Fig. 1).

The character of the Earthquake. — The character of the earthquake is no doubt of a tectonic origin. So it is better to look briefly upon the geotectonic relation of the region. The terrain devastated by the earthquakes consists of the tertiary formation in a deep trench (Graben), bounded by the large dislocations cutting the mesozoic limestones. This tertiary formations shows step-faults in the Canal region of Korinthos, as we can see them clearly on both walls of the Canal outting. An horst, which is about 60 m high above S. level, runs in the direction NWW-SEE across the Canal. The faulted steps step down from this horst to the both sides; NW and SE. The faulted steps on the side of the Korinthos Bay seems to be continued towards NNW and then to NW to the characteristic

broad steps or terraces (better we call them «step terraces») between the City of Korinthos and Kiaton.

The extensive step-terraces due to the step faults in the South West side of the Bay of Korinthos shows a large contrast to the steep coast line NE of the Bay. This geomorphological assymetry of the Korinthos Bay is probably caused by the step-fault movements of the tertiary terrain.

Actually the tectonic disturbances on the eastern extremity of the faulted zone in the northern part of the Korinthos Isthmus, caused probably the earthquakes. Such disturbances are subterranean and only a small trace of fissure along the ancient fault line, found by the Canal, scarcely suggests the tectonic movements in the depth.

The towns and villages near this zone, such as Korinthos, Lutraki and Kalamaki are damaged at most by the earthquake. The coastal zone between Korinthos and Kiaton can be considered morphologically and tectonically one single block. If this block moves due to the disturbance in its eastern extremity, then the villages on it might suffer the shocks in an almost same degree. This might be the reason why the disastrous region extends to NW so far.

The periodical movements of such a step fault zone seems to have been the *Heredity* in this region, from geological time and each movement causes the destructive earthquakes in the vicinity. The earthquake-Heredity of this district will continue in the future and then the epicenter of the earthquake will be in the vicinity of the actual Korinthos. Though the site of the actual Korinthos, therefore, will be changed in the vicinity, for example on such a place as the Military exercise yard on a broad step terrace, just south of the city, the future earthquakes will be almost equally sensible as now.

The Renascent of the City of Korinthos.—Judging from the conditions of the disturbances of the earth surface and of the destructions of the buildings, the earthquakes of Korinthos were by no means so big as those of Messina 1908 and Avezzano 1915 in Italy, which I visited personally after the catastrophes.

Due to the careless constructions of houses to the seismic vibration, the disaster of the shocks in Korinthos, however, was extraordinary heavy in comparison with its magnitude. From such reason, it is better to reconstruct the city in the actual location and to build the houses

antiseismically, so that the future Catastrophes will be avoid to a certain extent. Therefore the renascent of the City of Korinthos, we regard specially this important port or harbour City now, is a question of architecture.

In the following I add a few lines of the condition of study about antiseismic constructions. The engineer members of the Earthquake Investigation Committee have been eagerly active in studying the effects of shocks, both natural and artificial, upon different structural elements of various kinds of buildings.

By their efforts a standard method of antiseismic constructions has been gradually established. Actually, a member of brick buildings constructed after their designs have beautifully stood the most severe test in the form of the large earthquake in September 1923, while a remarkable contrast, some of the reinforced concrete buildings of modern design with no precaution against earthquakes have suffered considerable damage. It is desirable to put a seismological observatory in Korinthos, where not only violent shocks, but also the minimal slow deformation of the earth crust could be measured with Clinographs (for example the model of Dr. ISIMOTO in Tokyo), tide gauges etc. It is possible that the earthquakes will be accompanied by the deformations of the earth surface before the large shocks, just as many cases in Japan showed. If we can predict the large catastroph from the observations of such preliminary phenomena, it will be a great help for the people of the earthquake regions.

ΧΩΡΟΓΡΑΦΙΚΗ ΓΕΩΛΟΓΙΑ. — Die Verbreitung kretazischer Foraminiferen in der westgriechischen Olonos-Pindoszone*, von

H. Carl Renz. Ἀνεκρινώθη ὑπὸ τοῦ κ. Κωνστ. Α. Κτενᾶ.

In einem der Akademie von Athen am 24. Nov. 1927 vorgelegten Bericht¹ hatte ich von zahlreichen Stellen des thessalischen Pindos Orbitoiden angeführt, die hier in brecciösen Kalken zusammen mit Hippuritenfragmenten auftreten und der Oberkreide zugewiesen wurden.

* ΚΑΡΟΛΟΥ ΡΕΝΤΣ.—Ἡ διάδοσις τῶν Τρηματοκόγχων τοῦ Κρητιδικοῦ εἰς τὴν ζώνην τοῦ Ὠλονοῦ-Πίνδου τῆς δυτικῆς Ἑλλάδος.

¹ CARL RENZ: Geologische Untersuchungen im thessalischen Pindos. *Πρακτικὰ τῆς Ἀκαδημίας Ἀθηνῶν* 2, 1927, σ. 455.