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ON THE SEISMIC ENERGY AND THE AGE OF THE EARTH

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The maximum seismic energy estimated hitherto is of the order of 10^{25} ergs. It is only 1/5 of total solar energy received by the earth in one minute. If only a small part of this solar energy can be available to the occurrence of earthquake, it is sufficient to it. But the solar energy cannot penetrate into the deep part of the earth's crust where earthquake occurs. It is, therefore, not important in the seismology.

One who observe faults or warping of the earth's crust in the cases of large earthquakes tends to consider the yielding of the earth's crust as the cause of the earthquake. But yielding of the earth's crust itself must have some other source of energy. Such a source of energy must be the inequality of temperature. Inequality of temperature must be caused by either inequal cooling or heating. JOLY attributes it to the distribution of the continental mass, which covers the layer of sima, and is main source of radioactive heat. He tried to explain the geological revolutions by it. But there are much larger sources of energy ever ignored.

In this paper, the author tried to compare the amount of heat evolved by various sources.

§ 1. Radioactive Heat.

The heat evolved by the radioactive disintegration in the earth's crust is some 15.9 calories or 66.8×10^{7} ergs per year per metric tons of rock. If the density of rock be 2.8, one cubic kilometer of rock has the mass of 2.8×10^{15} grs. or 2.8×10^{9} metric tons, and it evolves the energy of 1.87×10^{18} ergs per year. The radioactive heat evolved in one cubic kilometer of rock can cause a single earthquake every 5.4×10^{6} years. As the total area of the earth is about 5.1×10^{8}km^2, if such a radioactive layer has the thickness of 10.6 m, it can cause one largest earthquake every year. But as the heat evolved in oceanic area is continually radiate out as JOLY stated, thickness of active layer must necessarily be 36 m. This is sufficiently large to explain the present seismic activity.

But the fact that igneous rocks intruded in sedimentary rocks in different geological eras have different uranium-lead ratios, must be explained by that uranium had not radioactivity before it intruded into surface layers, because uranium is quite dispersed mass in rocks and cannot be totally separated from lead yielded by it when it intruded. On this point the author will discuss in details in other case. The radioactive heat ever estimated cannot, therefore, be acceptable.

§ 2. Depresson of Rock Layer.

Geographer ever classified earthquakes into three different kinds. One of them was caused by the depression of rock into underground cavity. One cubic kilometer of rock with the weight of 2.8×10^{15} grs. is assumed to fall down 1 m. Its energy is 2.74×10^{20} ergs. To cause a large earthquake of the energy of 10^{25} ergs, rock of 10km^3 must fall down a distance of 36.5 m. It may be, therefore, very rare to cause the largest earthquake in this mechanism.

§ 3. Atomic Explosion.

Atom-bomb yields considerably large energy. When a large atom-bomb explodes in the interior of the earth, will it cause large earthquake? ${}_{92}U^{235}$ yields an energy of 2×10^8 electronvolts or 3.2×10^{-4} ergs per atom. As the weight of an atom of ${}_{92}U^{235}$ is about 3.92×10^{-22} grs, energy of 8.2×10^{17} ergs can be evolved by 1 gr. of ${}_{92}U^{235}$. 12.2 metric tons of ${}_{92}U^{235}$ is, therefore, necessary to cause a largest earthquake. As ordinary uranium contains only 0.71% of ${}_{92}U^{235}$ and only 5×10^{-17} grs of uranium in one gram of rock, 0.34×10^{26} grs or 12.3 cubic megameters of rock is need to cause largest earthquake. It is quite impossible to collect such a large mass of ${}_{92}U^{235}$ from such a large volume of rock. It is quite impossible to collect uranium at a place to cause spontaneous explosion.

§ 4. Latent Heat of Fusion of Rock.

The latent heat of fusion of rock when it crystallizes from amorphous state is about 100 cal/gr. or 4.2×10^9 ergs per gr. If a mass of 1 km^3 of rock whose density is 2.8 crystallizes, energy of 1.18×10^{25} ergs can be freed. To cause a single largest earthquake, only 0.85 km^3 of rock is necessary to crystallize. If this is distributed on the whole area of the earth, its thickness is only 1.67 microns. If the oceanic area is neglected as JOLY stated, it is 5.7 microns.

§ 5. Heat of Oxidation of Rock.

Elements contained in igneous rocks are all in the state of oxides. What elements are there in the interior of the earth is little known. But it is certain that in volcanoes oxidation of gases at the crater plays an important *rôle*. From this fact it may be quite natural to suppose that oxygen is very rare in the interior of the deep part of the earth. If exclude oxygen from ordinary igneous rock, its constitution is as given in the following table.

Elements	Percentage of elements	Oxides	Heat of oxidation per gram	Heat of oxidation of each element in 1 gr. of mother rock.
Si	51.46	SiO_2	29580×10^7 ergs	15200×10^7 ergs
Al	15.08	Al_2O_3	30960	4700
Fe	9.48	Fe_2O_3	7180	700
Ca	6.74	CaO	15800	1100
Na	5.28	Na_2O	9022	500
K	4.81	K_2O	4616	200
Mg	3.90	MgO	15600	600
H	0.24	H_2O	142380	34200

Sum 57200.

The heat of oxidation of 1 gr. of the supposed mother material of rock is 57200×10^7 ergs per gram. Even if hydrogen is excluded, it is 23000×10^7 ergs per gram. On the density of such a mother material is nothing known. If the elements are purely mixed, its mean density is 2.7. Therefore tentatively assume it to be the same of ordinary rock or 2.8. Then 0.1—0.05 km^3 of such a mother material is sufficient to evolve an energy of 10^{25} ergs. If this mother material is distributed on whole area of the earth, its thickness is only 0.2—0.1 microns. And if it be distributed only in continental area the thickness is 0.6—0.3 microns. It is of cource not necessary to distribute in a uniform layer. 0.1-0.05 km^3 of such a mother material of rock at the origin of earthquake oxidizes, then one largest earthqauke can be caused.

§ 6. Conclusion.

The largest possible energy source of seismic activity is the oxidation of the mother material of rock. Only 0.05–0.1 micron of layer or 0.05–0.1 km^3 of it is sufficient for it. The heat of crystallization of amorphous rock is next large one 5.7 micron or 1 km^3 of rock is sufficient to crystallize. Radioactive energy is also possible. But further large mass of rock must be necessary to attribute to the action. Depression of rock is not important. On the evolution of heat from radioactive substances, the author cannot accept it without further discussion.

Considering intermediate layer of the earth constructed by metallic alloy and oxidation of it at its very thin layer at the uppermost part or in a very small volume at the origin of earthquake, seismic activity can be easily explained. Volcanic and other tectonic activities are also explained by this assumption.

If 20 largest earthquakes to be assumed to occur every year, 10 microns of the mother material under continental area is need to oxidize. If in this same rate oxidation has undergone, formation of continents of 60 km thick takes 6×10^{10} years or thousand milion years. It is about 200 times of the age of Archaean rock, and nearly the same of that of the sun.

In this estimation the heat radiated out from the earth's surface is neglected. But the work done as tectonic, seismic, and volcanic actions must finally generate heat. These actions are to be regarded as non-efficient heat engine. The thickness of the radioactive layer is several km to maintain the observed geothermal gradient. The thickness to maintain present seismic activity is only 36 m, or about only 1/1000 parts are used for seismic action.

If other heat sources are taken in consideration the effeciency may be much lower.

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