ÒÈÕÎ ÎÊÅÀÍÑÊÀß ÃÅÎËÎÃÈß, 2002, òîì 21, №2, ñ. 74–84

УДК 551.24

THE ROLE OF MICRO-FRACTURES IN THE EXCESS MASS STRESS TECTONICS MODEL*

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In an anisotropic medium micro-fractures caused by Excess Mass (EM) solid ‘wedges’, increase in size and concentrate in time and space when the EM ‘wedges’ meet structural discontinuities-‘obstacles’, and serve as ‘resonant cavities’ wherein ‘old’ free electrons from the metallic bond of $Fe^{2,3+}$ and ‘new’ electrons from Fe^{2-} accumulate, resonate through ERSEME (Electron Resonance Stimulated by Excess Mass Electrons) and produce the high stress and strain rates, of the order of 10^{15} Pa·s^{-1} and 10^{-5} s^{-1} respectively, compatible with adiabatic change and earthquake generation. Secular weak stress rates of the order of 10^{-2} Pa·s^{-1} can only cause aseismic creep, i.e., 10^{-14} s^{-1}. A model is proposed in which a plastic material responds elastically for a band of frequencies between 10^5 and 10^{15} Hz. The type of fault, normal, reverse, or oblique is determined by the direction of the maximum compressive stress, which depends on the orientation of micro-fractures. In an isotropic medium, due to the lack of structural discontinuities, the accumulation of ‘old’ and ‘new’ electrons is not facilitated and resonance does not frequently occurr. Low seismic activity, oceanization-basification of the granitic continental crust, low velocity zones, volcanic activity, ophiolites, and finally juvenile oceanic crust basalts are the products of the symmetrical spatial and temporal distribution of micro-fractures.

Ключевые слова: **micro-fractures, excess masses, stress, tectonics.**

INTRODUCTION

One of the most important issues in understanding earthquake generation is how adiabatic change, i.e., high stress and strain rates, is produced. Plate tectonics and elastic rebound that consider rocks as an elastic medium, resort on horizontal secular stresses of the order of 10^5 to 10^7 Pa per year or per much longer periods of time, and on transferred stresses of the same order, fail to give a satisfactory answer to that question. Strain rates, caused by the action of such stress rates on a plastic medium without micro-cracks, are 10^{-13} to 10^{-15} s^{-1} [5], when the reported coseismal strain rates is many orders of magnitude greater, i.e., from 10^{-5} s^{-1} in faulting to 10^3 s^{-1} in seismic waves.

In the linear slip model and in the context of elastic rebound [11], micro-fractures 10^{-6} to 10^{-5} m in length [27], develop as a result of internal pressure increase and/or because of the introduction of a lubricant. Their presence increases the shear compliance of the medium, and the elastic response, of an otherwise weakened plastic medium is attributed to the micro-fracture filling material (Fig. 1). No explanation is offered as to the process of pressure increase, and as to the nature, origin and destination of the elastic material and the lubricant.

The assumed elastic deformation along both sides of a fault is not supported by observation. In most cases constructions along the San Andreas and North Anatolian Faults suffer no other damage than horizontal displacement. Similarly the exclusively aseismic creep along the hundreds of transform faults in ocean basins indicates that faults and elastic rebound do not relate to earthquakes as the cause and the effect.

Plate tectonics undermine the evident connection between seismicity and volcanism. It relates earthquakes to interplate boundaries – convergent, divergent, and transform – and attributes the intermediate volcanic rocks in island arcs to the melting of the subducting lithosphere. It also considers the basaltic ophiolites as obducted remnants of old oceanic crust. This approach fails to explain in a consistent way the origin of the different types of ophiolite suites, especially those found in intraplate areas, such as in the Urals. It also fails to give a reasonable source mechanism for deep and intraplate earthquakes. It is therefore imperative to find a model that, despite its possible reasonable agreement with observation that can be mainly attributed to the fact that non-dimensional functions – i.e., strain – remain constant over a wide range of variables – i.e., stress, viscosity, rigidity, time – do not violate known physical laws, do not constantly resort to ad-hoc interpretations, and can give persuasive answers to questions like:

1. Can rocks be considered as plastic or as elastic medium?

2. How can a plastic material, with viscosity of the order of 10^{20} Pa·s, respond elastically?

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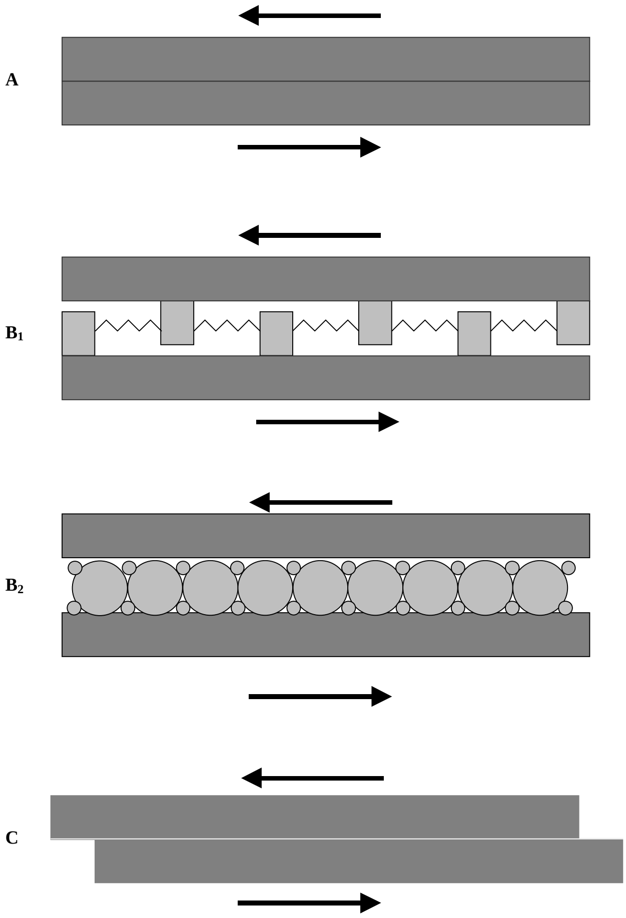


Fig. 1. The linear slip model according to the elastic rebound hypothesis.

A. The mass of rock without micro-fractures. Secular stress causes only very slow creep.

B_1. Micro-fractures develop as a result of the build up of internal pressure. Shear compliance increases. Note that the elastic element is the micro- fracture filling material.

B_2. The introduction of a lubricant has the same effect as the increase of internal pressure.

C. Due to weakening, the same, as in A, shearing stress causes slip.

The nature and the function of the micro-fracture filling material need to be explained.

3. What are the nature and the function of the micro-fracture filling material?

4. Is there a causative relationship between faults and earthquakes, or between micro-fractures, anisotropy, and earthquakes?

5. How are the different types of ophiolite suites produced?

THE EXCESS MASS STRESS TECTONICS (EMST) MODEL

In a series of papers [23–26] I have proposed the Excess Mass Stress Tectonics (EMST) model. The main points of this proposition are:

Processes inside the earth are the result of transformation of matter, in the direction of higher order and complexity. Self-differentiation and self-organization is the general trend in nature, and the cyclic part is only a small fraction of this dominantly irreversible process. In that context there is not one 'creation' event in the distant past, but many and ongoing transformation episodes.

The core is made of plasma, the fourth state of known matter, that is a mixture of neutral particles, positive ions, and negative electrons. The particles being electrically charged are capable of creating and reacting with electromagnetic fields. In the plasma state high kinetic energies could be the 'random' kinetic energy of heat, or the 'clustered' electromagnetic energy. Protons travelling with a speed of 10^7 m/sec, can produce shock wave pressures of the order of 10^{30} Pa, which is quite enough for their fusion to occur. In the outer core electromagnetically confined H and He, p^+, and n°, along with an excess of e^-, participate in resonance, shock waves, and cold fusions and form new atoms that are "injected" into the mantle. The newly formed atoms constitute the "Excess Mass" (EM) relative to the mantle, but not necessarily relative to the earth as a closed system. Q values, of the order of 10^4 in the outer core, indicative of a low friction state – as compared to 10^2 in the crust [4] – provide support to that proposition. These values are compatible with the low temperatures of electromagnetic clustering, and not with high temperatures and random movements. As for the inner core, it is probably the place where the neutral particles of plasma accumulate.

Resonance, electromagnetic clustering and cold fusion offer the mechanism for the Earth pulsation [18]. During periods of intensive electromagnetic clustering, due to the synthesis and emplacement in the mantle of new atoms, expansion takes place. Concurrently the degeneracy pressure of electrons is reduced, the effect being the earth's contraction. During periods of diminished clustering, the production of new atoms and expansion due to their emplacement is also diminished, but there is an increase of the degeneracy pressure and therefore of expansion. In both cases a net mantle and crust expansion due to the emplacement of Excess Mass (EM) in them is superimposed on pulsation. The rate and the extent of net expansion during the last 200 m.y. depend on the thickness of the primordial granitic crust.

About 200 m.y.a. earth had a smaller than its present size, i.e., a radius ~60% it present radius. A pan global continental-felsic crust, from 350 km to 700 km thick, covered early earth. The area covered was at least that of the present continents. Shallow and narrow epicontinental seas, that later evolved into the present oceans, trans-sectioned the all-encompassing continental crust. The slowing down, at a present rate of $\sim 2.5 \times 10^{-5}$ sec/year, of the earth's rotation rate, provides support to the notion of earth's expansion with constant mass. The question is, at what rate? Very long baseline interferometry (VLBI) data indicate radius increase rates of the order of mm per year; while tectonic uplift data, of the order of cm per year.

There were two major phases, with deviations of course, in the formation of elements. The pre-iron phase, when all elements and iron in minor amounts, i.e., banded-iron, were formed, and the iron phase during which massive production of iron occurred. The iron phase started about 200 m.y.a., in the Alpine orogeny, and still goes on at an exponentially increasing rate. Iron is the last element to form because, of all elements, has the highest nuclear binding energy of 8.8 MeV per nucleon. Also it is an established fact that earlier crust was continental and granitic in composition, and the oceanic-basaltic crust is younger than 200 m.y. The proposed interpretation is that the threshold of 8.8 MeV was more frequently surpassed during the last 200 m.y. leading to the formation of the earth's mantle and oceanic crust and being responsible for the basification of the primordial granitic crust. Of course the threshold of 8.8 MeV was occasionally exceeded in the time period before 200 m.y.a. Indicative of that are the Precambrian Cordilleran and the Paleozoic Caledonian-Appalachian-Hercynian orogens.

Due to bulging they cause, orogens develop in equatorial areas. For that to occur the earth must rotate relative to the poles, or otherwise the poles will appear to drift by an equal amount and in the same direction, relative to the earth. For example in the context of fixed poles, a clockwise rotation of North America by about

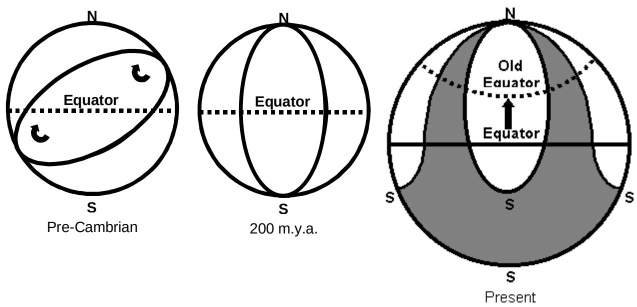


Fig. 2. An 'old' pan-global continental-granitic crust covered the whole earth from the Precambrian to about 200 m.y.a (white), and since then 'new' oceanic-basaltic crust (grey), was emplaced. Due to orogenic bulging that forced the bulged ring to become equatorial, a clockwise rotation, i.e., of Americas, by ~120° occurred from the Precambrian to the present. During the last 200 m.y. the rate of addition of Excess Mass into the 'old' panglobal crust dramatically increased, but it was greater in the southern hemisphere and as a result the continents and the south magnetic pole underwent apparent east-west drifting and northward tilting by ~35°. This plane of tilting is almost at right angles to the plane of clockwise rotation due to equatorial bulging.

120° has occurred since the Cambrian [6]. This rotation is independent of the rate of expansion and is qualitatively and quantitatively similar to that on a constant size earth. During the Alpine orogeny when the expansion rate is thought to have dramatically increased in general, but at a faster rate in the southern hemisphere, there was a northward tilt of the Mesozoic equator by about 35°. That tilting was at right angles to the plane of rotation due to equatorial bulging (Fig. 2).

Seismic activity, volcanism, gravity and magnetic anomalies, and heat flow [20] are manifestations of "Excess Mass".

ELASTICITY, PLASTICITY, AND MICRO-FRACTURES

In an elastic medium there is a linear relationship between stress, strain and time, and stress can be transferred, and trigger earthquakes (Fig. 3a). A stress increase transferred by a nearby earthquake will advance the time of generation of the next earthquake, while the opposite will happen in the case of a stress decrease. This is a deterministic model that corresponds to standing wave, i.e., the time dependence of the movement is the same everywhere in the medium. On the contrary a plastically deforming material can only respond elastically if it accepts the action of a high stress rate (Fig. 3b). Thus in plastic media the principle of uncertainty is involved, deformation is time and frequency dependent, and is produced by a high stress rate, which brings two particles closer to one another and as a result a quantum mechanical force of repulsion arises. The deformation process in a plastic medium resembles a travelling wave, i.e., the energy propagation has speed and direction.

In Figures 4a and 4b plastic media connected in parallel can deform plastically or elastically depending on the nature of the stress, i.e., volume and secular stress, versus surface and high stress rate. Adiabatic change can lead to elastic and brittle behavior in a plastically and isothermally deforming solid material. This is possible when there is a high stress rate, i.e., of the order of 10^{15} Pa·s^{-1} (10^{10} Pa/10^{-5} sec) that can produce a high strain rate, i.e., of the order of 10^{-5} s^{-1} (10^{-10} / 10^{-5} sec), as compared to stress and strain rates of the order of 10^{-4} Pa·s^{-1} (10^{6} Pa /10^{10} sec) and 10^{-14} s^{-1} (10^{-4}/10^{10} sec) correspondingly, in a plastically deforming material.

A volume-secular stress of 10^{6} Pa, acting on a plastic medium with viscosity, $\eta = 10^{20}$ Pa·sec, and rigidity, $\mu = 10^{10}$ Pa, causes isothermal deformation. The action of internal forces increases internal pressure, which in turn is responsible for the formation of micro-cracks that lower the overall viscosity of the plastic material, i.e., from 10^{20} to 10^{15} Pa·sec, and increase its shear compliance. In the in series connection a stress rate of the order of 10^{15} Pa·sec^{-1}, increases the effective rigidity, i.e., $\mu' = 10^{20}$ Pa, causes adiabatic change, and forces the plastic material to behave elastically for

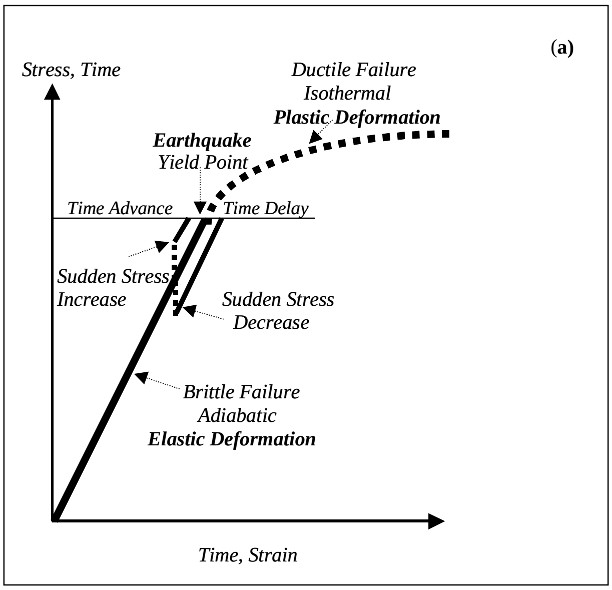


Fig. 3a. Elastic-plastic deformation in an elastic medium.

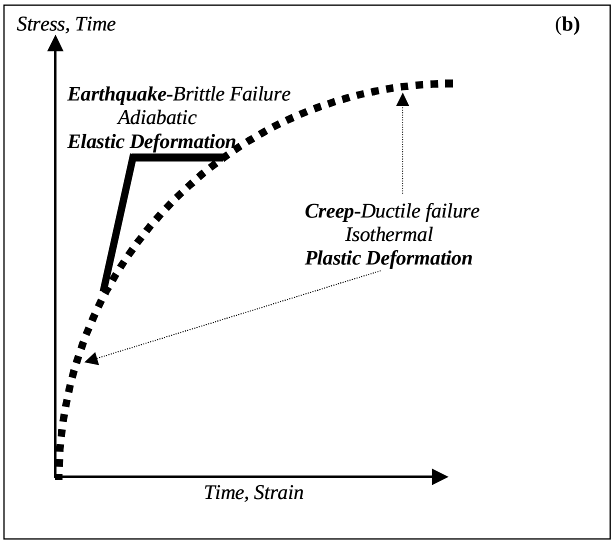
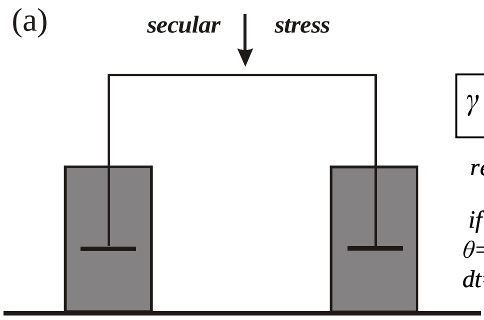


Fig. 3b. Plastic-elastic-plastic deformation in a plastic medium

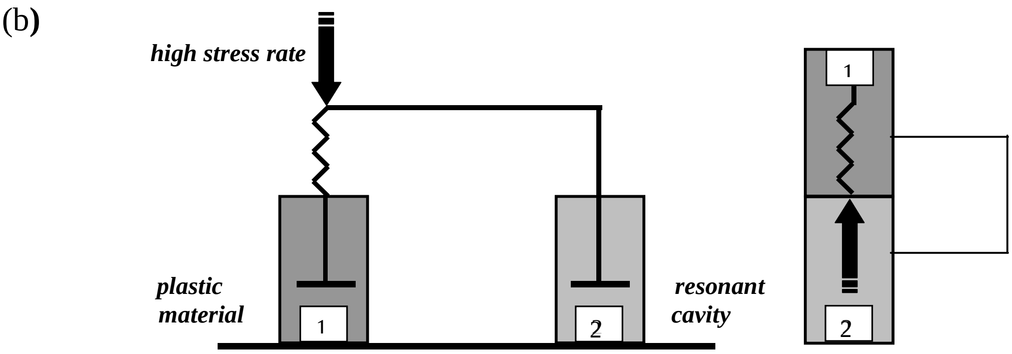


Plastic Material in Parallel

$\gamma = \frac{t}{h} dt$ $\gamma = \log(l/l_0)$, $l = l_0 + dl$

relaxation time, $\theta = \frac{h}{m}$ *, dt= time of action of stress*

if viscosity, $\eta = 10^{20}$ *Pa·sec, rigidity,* $\mu = 10^{10}$ *Pa®*
$\theta = 10^{10}$ *sec. If stress,* $\tau = 10^{6}$ *Pa®*
$dt = 10^{10}$ *sec, strain,* $\gamma = 10^{-4}$*, and* $l/l_0 = 1.00023$



Plastic-elastic Material in Series

$\gamma = \frac{t'}{m'} + \frac{t'}{h'} dt$

relaxation time, $\theta = \frac{h'}{m'}$

if $\eta' = 10^{15}$ *Pa·sec,* $\mu' = 10^{20}$ *Pa®* $\theta = 10^{-5}$ *sec*
if $\tau' = 10^{10}$ *Pa ®* $dt = 10^{-5}$ *sec*
if $dt < \theta$ *® elastic behavior, i.e.,* $dt < 10^{-5}$ *sec,*
if $dt > \theta$ *® plastic behavior, i.e.,* $dt > 10^{-5}$ *sec*

Plastic-elastic Material in Parallel

$\gamma = \frac{t'}{m'} + \frac{t'}{h''} dt$

time of afterworking, $\theta' = \frac{h''}{m'}$

if $\eta'' = 10^{5}$ *Pa·sec,* $\mu' = 10^{20}$ *Pa®* $\theta' = 10^{-15}$ *sec*
if $\tau' = 10^{10}$ *Pa ®* $dt = 10^{-15}$ *sec*
if $dt > \theta'$ *® elastic behavior, i.e.,* $dt > 10^{-15}$ *sec*
if $dt < \theta'$ *® plastic behavior, i.e.,* $dt < 10^{-15}$ *sec,*

Fig. 4. In the EMST model a high stress gradient produced in micro-fractures can force a plastic material to respond momentarily elastically.

periods lower than 10^{-5} sec, and plastically for periods greater than 10^{-5} sec. In that context strain hardening is not the result of the existence of a locked fault i.e., asperity or a barrier, but of the action of a high stress rate on a weaker than before (present viscosity 10^{15} Pa·sec, as compared to past viscosity of 10^{20} Pa·sec) plastic material.

In a neighbouring location, i.e., microfracture-resonant cavity connected in parallel, the viscosity is further reduced to 10^{5} Pa·sec, and the shear compliance is drastically increased. Due to elastic afterworking [21], the material deforms plastically for periods lower than 10^{-15} sec, and elastically for periods greater than 10^{-15} sec. Therefore in the in parallel connection of two plastic materials there could be a band of frequencies, in the example of Figure 4b between 10^{5} and 10^{15} Hz, in which they can both respond elastically, if the proper stimulus is provided.

The wave and frequency domains of deep focus earthquakes, that resemble these of nuclear explosions [19] – i.e., sharp and clear, high amplitude, low period first motion, quick damping of the high frequency P and S seismic waves – are in conformity with that model. As for the lower amplitude, the higher period and the greater overall damping of seismic waves in surface earthquakes can be explained by the permanently open micro-fractures in the upper 30 km of the earth. The implication is that unless there is an internal weakening process associated with micro-fractures and dilatation, major fracturing cannot occur. In their absence the energy required to disrupt interatomic forces is four to five orders of magnitude larger, i.e., 30,000 times [27]. Experimental data show that at pressures 10^{9} Pa and higher [5], i.e., at a depth of about 30 km, all micro-fractures close and the velocity of P and S waves increases with density, i.e., $V_p \cong (\text{density})^{\sim 1.5}$. In earthquakes the velocity of seismic waves is inversely proportional to density, i.e., $V_s = (\text{rigidity/density})^{0.5}$. In that context micro-fractures that weaken the rock and lower the velocity of propagation of seismic waves can be attributed to solid intrusions [1,2] that concurrently increase its density. In the absence of micro-fractures in the crust the attenuation of seismic waves of surface earthquakes would have been lower than that of deep focus earthquakes.

Heat energy in solids exists as the vibration of atoms and the intensity of vibration is proportional to thermal conductivity, and therefore to temperature. In the high pressure environment of the earth's interior the vibration of atoms is limited to nonexistent. Consequently the higher the pressure, i.e., the higher the depth, the lower the intensity of vibration, the lower the heat conductivity, and, as a consequence, the lower the temperature for a given amount of internal energy. It is evident therefore that internal energy is not equivalent to thermal energy. Internal energy can be electronic energy, i.e., the compressed electron orbitals of the Fe^{2-} anions, and heat can be characterized as random kinetic energy. On the other hand electromagnetic energy can be clustered, and, because of that, its efficiency is much higher. For example for the ionisation of iron 7.87 eV, or 1.26×10^{-18} J of electromagnetic energy are required. The equivalent thermal energy requires a temperature of the order of 60,000 Kelvin ($T=2E/3k$, where $k=1.38\times10^{-23}$J/K). Similarly for an electron to acquire a velocity of the order of 10^{7} m/sec a potential difference of only 285 Volts is required ($K.E.=W=QV=mv^2/2$, $V=mv^2/2Q$, where K.E., kinetic energy, V, potential (volt), m, mass, v, speed, and $Q=1.6\times10^{-19}$C). On the other hand the heat equivalent of that energy demands a temperature of 2,200,000 K (!) ($K.E.=3kT/2=mv^2/2$, $T=mv^2/3k$, where T, temperature, $m=9.1\times10^{-31}$ kg, $v=10^{7}$ m/sec, $k=1.38\times10^{-23}$J/K).

EARTHQUAKES, FAULTS AND MICRO-FRACTURES

If seismic moment is used as a measure of total energy involved in an earthquake, seismic efficiency, that is the ratio of elastic energy to total energy is, on the average, only 0.005%, indicating that almost the whole amount of work is used to overcome interatomic forces. Also the dominant role of micro-fractures and of the micro-fracture filling material that serve as resonant cavity and standing wave, respectively; the nearly exclusively plastic behavior of the inter-micro-fracture medium; and elastic afterworking as the process by which plastic media can exhibit elastic behavior, are emphasized. The ratio of elastic energy to heat in surface earthquakes is 1–5% and in deep-focus earthquakes increases to more than 10% [19], signifying an increase of elasticity, due to the diminished number of micro-fractures with depth, and in all cases the dominance of plasticity, since the absence of micro-fractures in the inter-micro-fracture material can only increase the seismic efficiency by one order of magnitude [11]. On the other hand, the Q factor of P waves in the outer core is compatible with an almost friction-free material and, in consequence, very low damping. This observation is more agreeable with electromagnetic resonance and cold fusion than with high temperatures and molten metals, i.e., nickel and iron.

The emplacement in the mantle of the newly produced in the outer core iron is taking place in a high static pressure environment, of the order of 10^{11} Pa, while the dynamic pressures in the outer core could reach 10^{30} Pa. In these conditions the 4s orbital of the iron atom is compressed down to the 3d orbital that can then be filled with 10 electrons, 5 more than without compression, forming the diamagnetic Fe^{2-} anion. Furthermore iron being negative ion can bond with hydrogen and form FeH_2. For the introduction into the atomic structure of the 5 extra electrons, a force of the order of 2×10^{-7} N per electron is required [12]. In a low-pressure environment, i.e., depths less than ~700 km, the Fe^{2-} releases the 4 to 5 extra electrons to become Fe^{2+} or Fe^{3+}, respectively, the 2×10^{-7} N per electron, as well as the hydrogen that can then combine with carbon to form hydrocarbons, i.e. CH_4. In turn iron as $Fe^{2,3+}$ combines with O^{2-} enters into the crystal lattice and forms the ferromagnesian minerals of the basaltic rocks. The free electrons of the metallic bond of preexisting and newly formed $Fe^{2,3+}$, as well as those provided by the Fe^{2-} can also be considered as plasma.

When iron and other atoms meet a structural discontinuity-'obstacle', i.e., the boundary of a different in composition and/or properties crystal, their atom-by-atom emplacement into the crystal lattice is impeded; Fe^{2-}/FeH_2, that due to decompression can release hydrogen and 5 electrons, start to accumulate at that location, to increase the micro-fracture pressure and/or can act as lubricants. As a result micro-fracture size increases to 10^{-6} to 10^{-5} m (Fig. 5). Micro-fractures increase shear compliance, and serve as resonant cavities. The free electrons of the metallic bond of preexisting $Fe^{2,3+}$ rush into the micro-cracks. The increased conductivity and the drop of geoelectric potential a few hours before the generation of an earthquake can be attributed to the rushing of free electrons from upper to lower levels towards the micro-cracks. This process is similar to the drainage of water in liquefaction.

Since the size of the micro-cracks is considered to be of the order of 10^{-6} to 10^{-5} m, the fundamental wavelength of a standing wave is of the same order, while fundamental frequencies of the order of 10^{14} to 10^{15} Hz, which correspond to thermal and visible light radiation, can develop and thus explain earth's heat flow. According to E = hf (h = 6.63r10^{-34} Joule.sec, and f = 5×10^{14} Hz) that frequency corresponds to 3.3×10^{-19} Joules per electron. Assuming that in the metallic bond there are two free electrons per iron atom, then about 3×10^{40} electrons and 10^{22} Joules are available to resonate if the proper stimulus is provided. The stimulus-shaking force is provided by the excess mass (EM) electrons, in this case electrons from the Fe^{2-} ions.

The microcracks-resonant cavities allow the free electrons of the metallic bond, hereafter called 'old' electrons, and excess mass electrons, i.e., electrons from Fe^{2-}, hereafter called 'new' electrons, to resonate, that is to form an amplitude maximum of a standing wave, and thus produce the 'hammer blow' and the adiabatic change. The 'hammer blow' is necessary for an otherwise plastic solid material, outside the resonant cavity, to exhibit an instantaneous elastic behavior. We call this process ERSEME after Electron Resonance Stimulated by Excess Mass Electrons. The 'erseme' is fueled by the internal energy, in the form of compressed electron orbitals of Fe^{2-} ions. At the same time the excess mass iron 'oceanizes' the surrounding rocks since it forms ferromagnesian minerals that enter into the crystal lattice. This process can explain the ultrabasic intrusions and sheeted dykes in granite outcrops, which are common in intra-continental areas, i.e., China [7].

In the EMST model the accumulation and release of stress originate at the weakest location, which is also the area of maximum seismic intensity [7]. In the asperity and barrier models [19] stress accumulation and release occur at the strongest location, i.e., locked fault. This consideration is in contradiction with the observed phenomena associated with the earthquake preparatory process that involves micro-cracks and dilatation, i.e., weakening, at the very location where the earthquake originates. In other words elastic rebound is inadequate and horizontal volume stress cannot provide the high stress gradient, the 'hammer blow', which is required for the genesis of an earthquake.

In the EMST model faults are considered as the products of unification of micro-fractures. Their type, i.e., normal, reverse, or oblique, as well as their dip and orientation depend on the direction and the plunge of the internal compressive stress, σ_c, relative to the horizontal plane. If the plunge of the compression axis is

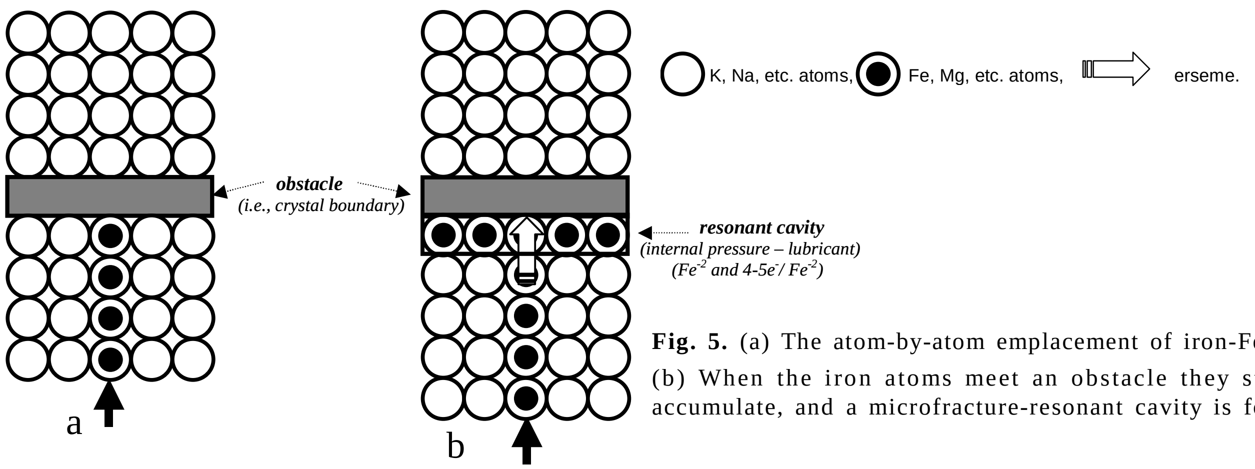


Fig. 5. (a) The atom-by-atom emplacement of iron-Fe^{2-}. (b) When the iron atoms meet an obstacle they start to accumulate, and a microfracture-resonant cavity is formed.

from 30° to 60° the fault is oblique, which is the most common case in surface and mainly in intermediate and deep shocks. When the plunge of σ_c is from 60° to 90° the fault is normal, and if from 0° to 30°, the fault is reverse (Fig. 6). In that context the occurrence of compressional earthquakes in the tensional environment of mid-ocean ridges finds a reasonable explanation [9,28]. It is not the horizontal-surface tectonic forces-features of the regional geology that are responsible for the genesis of an earthquake, but the deep sited inherent activities in rift zones [7]; and, the spatial distribution and characteristics of microcracks-resonant cavities is the decisive factor that determines the type of fault.

Along with dilatation and micro-cracks, in which resonance occurs, a fundamental prerequisite for the generation of an earthquake is anisotropy and inhomogeneity. Internal forces and anisotropy can explain why almost the total amount of seismic energy is released in continental and continent-ocean boundary areas, i.e., andesite line, and why sheeted dykes are met in these environments, and are practically absent in ocean basins. The symmetrical, in time and space, introduction of new atoms-excess mass (EM), is responsible for the well-defined LVZ below mid-ocean ridges, while in the more anisotropic and inhomogeneous continental crust LVZ are practically absent. The asymmetrical distribution-local concentration of EM, and the greater thickness of the crust, are the factors responsible for the release of the 95% of seismic energy in island arc and in continental areas, while in mid-ocean ridges only ~3% of seismic energy is released.

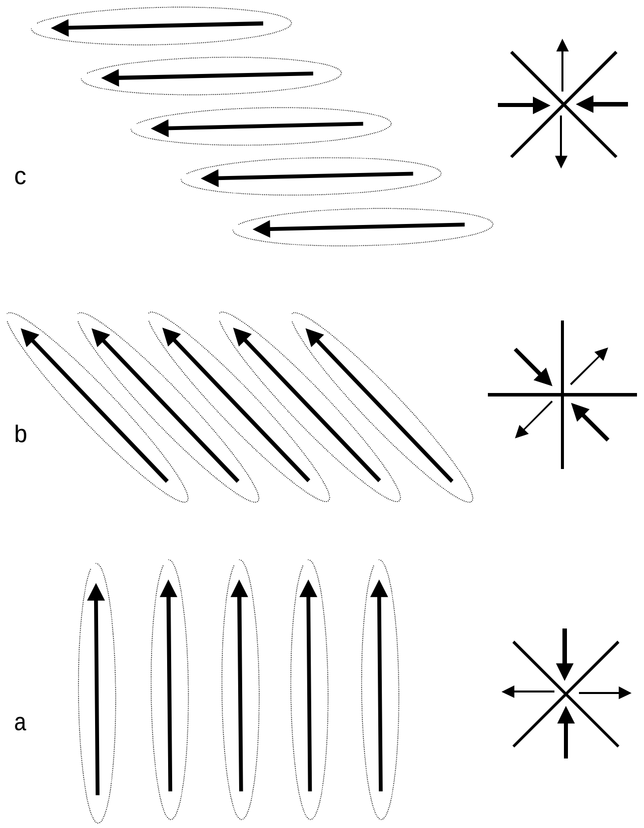


Fig. 6. The size and the orientation of the microfractures-resonant cavities determine the direction and the magnitude of the maximum compressive stress, and the type of fault.

(a) normal fault, (b) oblique fault, (c) reverse fault.

An earthquake with magnitude 8.8 Richter, which is about the maximum known magnitude, releases 10^{18} Joules of elastic energy. This is also the total amount of elastic energy released annually, and is an insignificant fraction of total energy (seismic moment), which is of the order of 10^{22} Joules. The difference is due to the work required to disrupt the electromagnetic forces between atoms and molecules in the crystal lattice. Considering that the rigidity, μ, is of the order of 10^{10} Pa then the volume change, ΔV, is of the order of 10^{12} m^3. That volume corresponds to a cube with a side of 10 km or to a sphere with a radius of 6.2 km. The strain energy per unit volume is of the order of 10^{10} Joules/m^3 and the compressive stress, $\sigma = 1.7\times10^{10}$ Pa (S.E./m^3 = σ^2 /6G, where G is the shear modulus taken equal to 5×10^9 Pa). Since the strain energy is per unit volume the stress is not a function of magnitude, i.e., is the same for small and big earthquakes. What differs is the corresponding force, i.e., total area, which in the case of an earthquake of magnitude 8.8, or 10^{22} Joules, is of the order of 2.4×10^{18} N ($F=\sigma \times S.A._{sphere}$, where S.A., surface area).

Assuming an average density of Excess Mass (EM) equal to the average density of the mantle, i.e., 4500 kg/m^3, the earthquake related EM, Δm_e, added annually in the mantle and the crust is 4.5×10^{15} kg. That amount is about one order of magnitude smaller than the annual rate of addition of excess mass calculated with other methods [8, 23]. If about one third of Δm_e is Fe atoms, i.e. 1.5×10^{15} kg, then about (1.5×10^{15} kg/ $56\times1.67\times10^{-27}$ kg =) 1.6×10^{40} iron atoms as Fe^{2-} that can be engaged in earthquake generation are being added every year in the mantle and the crust.

Considering that in a low pressure environment, i.e., at a depth less than 700 km, each Fe^{2-} can contribute up to 5 ‘new’ electrons, and each freed electron delivers 2×10^{-7} N, then about 10^{24} of Fe^{2-} anions can provide the force of 10^{18} N (10^{18} N / $5\times2\times10^{-7}$ N $=10^{24}$ Fe^{2-} ions). This is an incredibly small number when compared to the total number of 10^{40} excess mass iron atoms that are available.

The ‘new’ electrons from the Fe^{2-} anions and the ‘old’ electrons from the $Fe^{2,3+}$ cations can be considered as traveling waves, while in resonance they form a standing wave. In standing waves the boundary conditions, i.e., length of resonant cavity, L, determine the fundamental wavelength, λ_1, i.e., $\lambda_1 = 2L$, and the mode-wave number, while dynamics determines the frequency. Frequency f_n, is proportional to the mode n, and to the shaking force F, and inversely proportional to the size of the resonant cavity L, and the mass density $c_{m,}$ according to the formula $f_n = (n/2L)(F/c_m)^{0.5}$. If n=1, $L=10^{-6}$ m, $F=10^{-7}$ N, $c_m = 10^{-23}$ kg/m, the fundamental frequency is of the order of 10^{14} Hz, which is also the frequency of infrared-heat radiation and of vibrations in molecules [10].

If the 'old' electrons are considered aligned in a string, i.e., a polarized traveling wave, the required number of 'new' electrons for their resonance to occur can be estimated from the formula: Power = S $(\rho_m \times \omega^2 \times z_o^2 \times v)$, where $\rho_m = 10^{-23}$ kg/m, (c_m is the mass density per meter of about 10^7 aligned electrons per resonant cavity), frequency ω = 2pf (f = 5×10^{14} sec^{-1}, for n=5), amplitude, $z_o = 10^{-6}$ m, and speed v =10^8 m/sec [v = (Force / Mass Density)$^{0.5}$, where force 10^{-7} N]. Note that the power is proportional to the squares of both the amplitude and the frequency. By substituting it comes out that the power delivered by the 10^7 EM electrons is 5000 Watts (Joules/sec). The energy equivalent on an annual basis is 1.6×10^{11} Joules per resonant cavity, that is per 10^7 EM electrons, while the energy required is 10^{22} Joules that corresponds to about 10^{18} of electrons and to about 10^{11} resonant cavities. On the other hand, in a real earthquake of magnitude 8.8 Richter the energy density is much higher and the number of 'new' electrons needed is of the order of 10^{24}, while about 10^{17} resonant cavities are required.

Electrons, iron atoms, and the 'cloud' of rock grains produced by the strike can also resonate and exhibit elastic behavior and simultaneously cause the damping of waves, especially the high frequency ones. Heat generated in a grain is proportional to its volume and its rate of exchange depends on the size of the grain surface. For a given volume the greater the number of parts into which is divided the greater the total surface area. Therefore the smaller the size of aligned grains that vibrate, the greater the elasticity, but at the same time the greater the total surface area, and the greater the losses of mechanical energy due to the increased rate of heat exchange, and the quicker the temperature equalization with that of the environment, thus the greater the plasticity of the wave. The existence of permanently open micro-fractures in the upper 30 km of the earth's interior can explain the greater overall plasticity of the crust relative to the mantle. If it were not for the micro-cracks the attenuation of seismic waves in the crust would have been lower. On the other hand the high frequencies and the high amplitudes of P and S waves, relative to the following waves, as well as the faster damping observed in underground nuclear explosions and in deep earthquakes can be attributed to increased plasticity that goes along with increased elasticity. The latter implies greater effective rigidity and/or a higher stress gradient.

Therefore the heat engine earth concept, elastic rebound and the theory of elasticity in general, which is the mechanics of continuous media, are not applicable in a plastic medium with micro-cracks, i.e., discontinuous medium, which is the state of rocks before and after the genesis of an earthquake. Elasticity theory is applicable only at the instant of earthquake generation.

In the EMST model before and after an earthquake rocks deform plastically. During the earthquake preparatory process iron atoms, hydrogen and electrons provided by them increase the internal pressure, act as lubricants, disrupt atomic and molecular forces and form the micro-cracks. In the presence of structural discontinuities-'obstacles', that is of anisotropy, they accumulate in time and space and stimulate their resonance that produces the high stress rates required for the generation of an earthquake.

BASIFICATION-OCEANIZATION AND MICRO-FRACTURES

In the context of the EMST basification-oceanization and earthquake generation are processes of common origin. What distinguishes the two is the spatial and temporal distribution of micro-fractures, which in the oceanization process is chaotic and therefore symmetrical, and is attributed to the limited presence or complete absence of structural discontinuities-'obstacles' that denote a less anisotropic and therefore a more isotropic medium.

Basification-oceanization starts with the transformation of the primordial granitic continental crust through the emplacement of Fe, atom-by-atom, into the lattices of preexisting alkaline crystals, and ends with the accretion of kindred material in deep ocean basins (Fig. 7a-g). The emplacement is presumed to occur atom-by-atom because much less work is required than for the simultaneous emplacement of many atoms. For example in the atom-by-atom dislocation the necessary stress is 10^3 to10^4 times smaller than that for the simultaneous displacement [27].

Primordial granitic crust made of alkaline crystals formed from 4.5 b.y.a. to 200 m.y.a., and the K, Na etc. were placed as solid intrusions. The process starts in mobile continental belts, i.e. the Urals. The atom-by-atom introduction of Fe into the crystal lattice causes micro-cracks and dilatation, and releases electrons, and almost exclusively radiant heat. Surface melting and re-crystallization of granite takes place, and rhyolite is formed. The first ophiolites that formed in these continental fold belts were of the homodromous type, i.e., Paleozoic Continental Type Ophiolites (CTO) of the Urals [13]. The sequence of the volcanics is basaltic at the bottom, andesitic in the middle, and dacitic at the

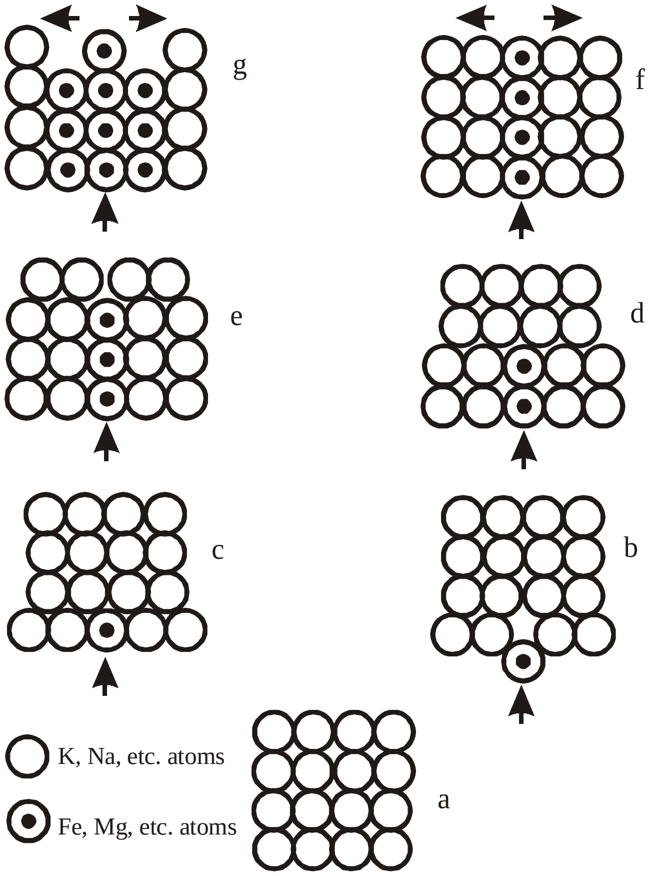


Fig. 7. Schematic representation of the basification-oceanization process in the context of EMST.

(a) Premordial granitic crust. (b)-(c) Continental Type Ophiolites-CTO. (d) Eastern Mediterranean -Tethys Ophiolites-EMTO. (e) Island Arc Ophiolites-IAO. (f) Mid-Ocean Ridge Basalts-MORB. (g) Typical Oceanic Crust-TOC basalts.

top. The ferrous siliceous jaspers, and the lack of pelagic ooze and clay are indicative of shallow waters.

A typical example of basification in epi-continental sea areas is the Eastern Mediterranean-Tethys Ophiolites (EMTO). In that region the volcanics are highly differentiated. The lower part of the volcanic sequence is calc-alkaline effusives, and the upper part is made of basalts. Triassic-Jurassic pre-ophiolitic sedimentary volcanics are present.

The Island Arc Ophiolites (IAO), i.e., the andesite line of island arcs, are rich in Na,K, Li, Sr, Ba, and poor in Ti,Zr,V,Cr,Co,Ni. The sequence of the explosive volcanics is Miocene acidic rhyolites at the bottom and basalts at the top. The presence of siliceous diatomaceous sediments implies lower temperatures and greater depths, up to ~ 4000 m.

The last to form in a continental crust environment are the Mid-Ocean Ridge Basalts (MORB). The granitic primordial continental crust splits, and the formation of an ocean basin begins. The MORB are poor in K, Rb, Sr, Ba, and rich in Ti, Zr, V, Cr, Ni. The volcanics of the troughs are the poorly differentiated glassy nepheline-olivine poor, calcium rich, tholeite basalts of the effusive Pacific type, and the olivine rich, alkali and calcium poor, basalts-peridotites of the explosive Atlantic type, which are similar to the Hawaiian lavas. Alkaline basalts rich in Ti characterize the margins [13]. Tension, melting and re-crystallization occur on or very close to, the surface, and the presence of carbonate sediments denotes the high temperatures of hydrothermal solutions.

Finally deep ocean basins and Typical Oceanic Crust (TOC) juvenile basalts form. Their deposition is not necessarily taking place parallel to mid-ocean ridges, but most likely in a patch-mosaic pattern, leaving chunks of old continental crust in between. Three criteria can be used in determining TOC: 1) Absence of intermediate and felsic components, 2) Thickness less than 7 km, and 3) Depth of deposition, i.e., greater than ~3000 m. By measuring the area coved by TOC we can determine the rate of expansion. All other ophiolite suites are presumed to be related to the transformation of the preexisting continental-granitic crust. The production of TOC ophiolites results into an area and volume increase of ocean basins. In that context oceanization-basification can be considered as a process of accretion that starts with the destruction and transformation of the preexisting continental crust and ends with the emplacement of juvenile basic volcanics in ocean basins.

As to the sheeted dykes, the issue in the context of EMST is solved. Sheeted dykes form at the first stages of oceanization and thus are expected to be readily found in the more anisotropic and inhomogeneous continental and island arc regions, and to a minor degree in mid-ocean ridges (Fig. 7b-f). In oceanic basins, where there is no structural, textural, or compositional difference between the emplaced juvenile and the surrounding rocks, in other words, the material is more isotropic and homogeneous, their absence is presumable (Fig. 7g).

THE ROLE OF INERTIAL SECULAR STRESSES

Inertial forces, due to the Earth's rotation, act on three dimensions and play a decisive role in geodynamic processes [22]. The core leads the mantle eastward, and the mantle leads the crust. If the reported annual eastward lead of the core by ~3° [16] proves to be correct it will mean a strain rate of the order of 10^{-9} s^{-1} and a shear stress rate of the order of 10^{3} $Pa{\cdot}s^{-1}$. Inertial forces acting on the surface of the Earth are the eastward lead of the southern hemisphere relative to the northern hemisphere, which if flattened and being the 'continental' hemisphere, stands about 2.5 km higher relative to the southern hemisphere, and because of that has a greater moment of inertia and lags westward relative to the southern hemisphere [6].

Similarly the Alpine-Tethyan zone lags westward, less relative to the northern and more relative to the southern hemisphere. The oceanic crust is also leading eastward relative to the continental crust. Due to the centrifugal force there is a movement towards the equator in both hemispheres. Another inertial force is the earth's tidal interaction with the moon [14, 15]. Therefore inertial forces can very well explain the dilatation and the presence of marginal seas along the eastern coast of Asia, as well as the compression and the lack of marginal seas along the western coast of Americas. Differential movements due to inertial forces can also explain the E-W trending wrench -transform faults of ocean basins as well as the San Andreas and the North Anatolian faults [6].

DISCUSSION

Micro-fractures are the result of micro-fracture pressure increase and/or of the introduction of a lubricant, while a weak stress can only cause slip. In the EMST model static and dynamic friction are drastically reduced and a metastable structure becomes unstable, collapses and slips under the action of a minor stress, i.e., gravity. As a result of rolling, stretching and sliding heat is released. The greater the number of micro-fractures the greater the shear compliance and slip will be. As in liquefaction, gravitational sliding requires a close-packed metastable state and a sufficiently high external shear stress, or an internal source that can provide that stress. Therefore in the EMST model gravity or any other inertial weak secular stress, i.e., rotational or tidal stress can cause sliding, but not an earthquake.

In both natural shocks and nuclear explosions elastic behavior is associated with brittle fracture, which occurs parallel to the compression axis and normal to the tension axis, and is the result of a high stress gradient. Contrary to nuclear explosions though deep focus earthquakes exhibit the shear and elastic rebound characteristics of shallow shocks implied by the quadrantal distribution of compressions and dilatations of P phases. The explanation proposed is that in nuclear explosions the formation of micro-cracks did not precede, as in the case of naturally occurring earthquakes. In the presence of micro-fractures rupture will proceed as shear fracture, i.e., at ~45° to the maximum principal stress σ_1 (compression), and the minimum principal stress σ_3 (tension). That happens because the shear strength ϕ_s, is smaller than tensile, σ_t, and, of course, than compressive strength, σ_c, i.e., $\tau_s = \sigma_c\sigma_t / \sigma_c + \sigma_t$ [27]. In other words, and according to the strength theory, of all planes having the same magnitude of normal stress the weakest one, on which failure is most likely to occur, is that with the maximum shearing stress. Surface transform faults and oblique faults of Wadati-Benioff zones have the same stress distribution, on the horizontal and the vertical plane, respectively. On the other hand, surface reverse faults associate with décollement and gravitational sliding, but not with earthquakes. This is the result of increased temperatures and increased plasticity due to the presence of permanently open microfractures in the earth's crust. In earthquakes and in faults is the maximum principal compressive stress, σ_c, that causes the elastic response and the brittle fracture and concurrently determines the type of shear fracture, and offers a reasonable explanation as to the origin of oblique faults, which the plate tectonics theory fails to do [1], i.e., no principal stress is on the horizontal plane. Thus micro-cracks associate with dissipation of heat, faulting and earthquakes, and the elastic energy in an earthquake is, on the average, just the 0.005% of its total energy.

According to the EMST model, heat produced and released in the micro-fracture rich upper 30 km of the earth causes melting, and recrystallization of preexisting felsic rocks. The produced volcanics have a different texture and composition than the parent rock. Later on in the ocean-continent transition zone, i.e., in island arcs, the iron atoms had enough energy to reach the surface and form ophiolites of the antidromous type, felsic at the base and turning mafic at the top [13]. In both cases if sedimentary rocks are present ductile stretching, which can be two to eight times greater than the horizontal distance between two points [17], metamorphic rocks and foldbelts will form. The last basalts in the time sequence are the juvenile Typical Oceanic Crust (TOC) basalts, which have the same composition as the mother 'protolyte' rock [3] that has the textural and compositional characteristics of olivine gabbro. The juvenile basalts fill the gap after the splitting of the oceanized continental crust, and are found in the deep ocean basins.

In summary, in the Excess Mass Stress Tectonics (EMST) model micro-cracks formed by the electro-magnetically and quantum-mechanically driven emplacement of Excess Mass, that is of iron as Fe^{2-}, and the emitted hydrogen atoms and electrons account for earthquakes, oceanization-basification, volcanoes, high heat flow, and possibly for the formation of oil. Inertial forces play a triggering role in the incidence of slip.

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Поступила в редакцию 10 апреля 2001 г.

С.Т. Тассос

О роли микротрещин в геотектонической модели "Избыточной массы"

В анизотропной среде микротрещины, вызванные появлением избыточной массы, увеличиваются в размерах и сливаются в более крупные микротрещины, "полости", которые служат резонаторами и накопителями для "старых" и "новых" свободных электронов. Скорость накопления определяет геотектонические процессы со скоростями деформации порядка 10-5·с-1, сравнимыми со скоростями адиабатических процессов, происходящих при землетрясениях. Предложена модель, в которой пластический материал отвечает упругими деформациями на возмущения в полосе частот 105 и 1015 герц. Тип разломов определяется направлением максимальных сжимающих напряжений, зависящих от ориентации микротрещин. В изотропной среде аккумуляция "новых" и "старых" электронов затруднена из-за отсутствия нарушений. И поэтому явление резонанса не так выражено, как в анизотропной среде. Низкая сейсмическая активность, океанизация и базификация гранитной континентальной коры, зоны низких скоростей, вулканическая активность, офиолиты и, наконец, базальты юной океанической коры являются продуктами симметричного пространственного и временного распределения микротрещин.