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Sodom and Gomorrah: Fires Created by Ignition of Combustible Gases by Earthquake-Impelled Thermobaric-Hydrothermal Explosions

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Abstract

Based on results of our tectonic-geochemical researches in the western Dead Sea area, which were published only as not easily accessible conference abstracts, proceedings, etc., as well as on new very relevant publications on Plio-Pleistocene mud-volcanism there, we attempt to show that some of the tectonic earthquakes in the area resulted in thermobaric-hydrothermal explosions and fires. This natural mechanism produced breccias with open spaces, concentric and radial fractures, caves and the patina containing micro-particles of soot and metals. Explosions of mini and medium scale have been apparently generated by earthquake-expelled heated to 120-150°C hydrothermal liquid transporting light hydrocarbons and hydrogen-sulfide. When reaching near atmospheric pressure it instantly becomes steam with corresponding volume increases of up to 1700 times. These give rise to the pulverization of hydrothermal stream and the escape of gases, and lower ignition temperatures of hydrocarbons and hydrogen sulfide; sparks ignite volatiles, ionized steam and atmospheric oxygen are oxidizers. Sparking is produced mostly by electricity, resulting from interaction of a high-velocity stream of a wet steam with solids. It is thought that not only Sodom and Gomorrah, but also other historical conflagrations devastating cities immediately after earthquake may have been caused by natural ignition of earthquake-expelled combustible gases. In case of very large volume of expelled gases the fire will appear high above the ground, on the uplifted by its intrusion contact-zone with the atmospheric oxygen; the fire will go down when the gas-stream lessens. Author's recommendation is that for prevention of major disasters, the construction-sites chosen for important nuclear or chemical plants in areas covered by loose sediments or in the vicinity of rivers should be examined for possible closeness to capable faults. Mapping of the He-outflow intensity is highly recommended. This is especially relevant in areas with known hydrocarbon occurrences and mud-volcanoes.

Keywords: Earthquake fires; Thermobaric-Hydrothermal explosions; Sodom and Gomorrah

Introduction

"...The Lord rained upon Sodom and upon Gomorrah brimstone and fire from the lord out of heaven; and he overthrew those cities, and all the plain, and all the inhabitants of the cities, and that which grew upon the ground and behold, the steam of the earth went up as the steam of the furnace..."

Genesis, 19:24-25, 28

Most readers of this article, professionals or persons simply interested in natural sciences, know the lines above by heart and thought at least once: what detail makes this biblical case miraculous? Probably, "fire from the Lord out of heaven"; all the rest is familiar from numerous descriptions of major catastrophic earthquakes. We would suggest one of the oldest, from the R.N. Captain Fitz Roy's (1839) description of the Adventure and Beagle 1835 voyage to Conception, Chile [1]:

"… Convulsive movements … The horrid motion increased; people could hardly stand; buildings waved and tottered – suddenly an awful overpowering shock caused universal destruction – and in less than six seconds the city was in ruins. The stunning noise of falling houses; the horrible cracking of the earth, which opened and shut rapidly and repeatedly in numerous places; the desperate heart-rending outcries of the people; the stifling heat; the blinding, smothering clouds of dust; the utter helplessness and confusion". "… The water in the bay appeared to be everywhere boiling; bubbles of air, or gas, were rapidly escaping; the water also became black, and exhaled a most disagreeable sulphureous smell. Dead fish were afterwards thrown ashore in quantities; they seemed to have been poisoned or suffocated". "… near Bacaloo Head an eruption burst through the sea… Smoke and water were thrown up during the greater part of the day, and flames were visible at night… As to the state of neighboring volcanoes, … I heard from Valdivia that directly after the earthquake all the volcanoes from Antuco to Osorno, inclusive, were in full activity" [1 pp. 403-418]. This description bears no resemblance to mechanical rebounds, but trains of monstrous explosions that uplift continents and trigger volcanic eruptions [2,3].

In his article "Geological events in the Bible" [4] Prof. Bentor explores the version of earthquake destroying the Sodom and Gomorrah cities and causing flood, which explains why Lot and his family escaped "brimstone and fire" climbing the steep Zohar mountain instead of running south along the plain (Figure 1). However, Bentor could not explain the fire by natural reasons, because there are no active volcanoes in the Dead Sea area and mud-volcanism remained an enigma in his time. So, he thought that "the editor of the [biblical] account surely felt justified in replacing the flooding by the much more impressive mechanism of fire and brimstone raining down from heaven, the abode of God" [4].

It is a common knowledge that many earthquakes were accompanied by conflagrations that killed many victims and burned their property (the great Lisbon quake of 1755; San Francisco, 1906; Tokyo, 1855, and too many others), which were explained as started "by kitchen-fires, which were left unattended by people who run for safety out of the buildings".

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Figure 1: Satellite map of the Dead Sea and the Judea Desert region (from the Satellite Map of Israel, 1993, Historical Productions Ltd., C.N.E.S.).

The authors of this article are geologist working at the Geological Survey of Israel (GSI), and an experienced physicist/chemist. They attempt to show the geological and historical evidences for earthquake-explosions and earthquake-fires in the Dead Sea area, and the natural mechanisms which may explode rocks and ignite fires anywhere where earthquakes happen and inflammable gases may be present. The article herein presents additional unpublished data on the hydrothermal-pyrometamorphic processes (mud-volcanism) in Israel and pioneers in analyzing the physics of these processes.

Local Geology

Israel extends along the Dead Sea Transform fault-zone separating the Arabian plate from the African plate, and earthquakes there are frequent. The geology of Israel was lately described by various authors in the Geological Framework of the Levant [5]. The exact locations of Sodom and Gomorrah have never been found, however most biblical researchers place them in the southern basin of the Dead Sea, about 400 m below Mediterranean sea-level (MSL), near the salt-diapiric ridge of Mt. Sedom and the municipal dwellings of Newe Zohar (Figure 1). This area is covered today by mixed clay and other alluvial fan sediments susceptible to liquefaction and by brine of the evaporation basins of the Israeli and Jordanian Dead Sea plants. Most of the region under consideration is situated on the western shoulder of the Dead Sea rift-type depression, which is of an 8 to 10 km structural depth, produced by the left-lateral S-N movement with a displacement of about 105 km along the Dead Sea Transform [6]. The area there is a part of Judea Desert, characterized by a bare, semi-arid, deeply dissected landscape, where the most intensive strike-slip faulting, block-rotation, massive dolomitization along fault-shear zones took place and Plio-Pleistocene high-temperature – low pressure pyrometamorphic rocks and hydrothermal mineralizations are well exposed (area "a", Figure 2).

Gilat mapped the geology on a 1:50,000 and a 1:20,000 scale of a 1,000 sq. km area that crosses Israel latitudinally from its western foothills southwest of Hebron to the Dead Sea basin [7]. He was able to concentrate later on the geomorphological and geochemical mapping of the strike-slip faulting in that territory, which belongs to the Syrian Arc and the Dead Sea systems. His tectonic-geochemical model explaining the mineralization activity in Judea was put forth [7] as follows: (a). Numerous strike-slip faults associated with the Dead Sea Transform are superimposed on and cut through the structures of the Syrian Arc in Judea; (b). At least some of the main monoclines of the Syrian Arc belt are bordered by and caused by oblique-slip faults; (c). The "Sinai-Levant micro-plate" has been broken into smaller blocks by dominantly horizontal dislocations, probably since the Mesozoic Era. Some of these strike-slips are still active and landscape-forming; they also operate as good conductors for magmatic intrusions, mantle helium (detected in oil and gas reservoirs in Israel in 1989 [8]), and circulating mineralizing solutions; thus the broken "micro-plate" can be evaluated as a potentially metallogenic province.

The surface outcrops comprise Cenomanian-Turonian limestones and dolomites, Santonian chalk overlain by Campanian chert layers alternating with phosphorite beds, by Maastrichtian chalk rich in organic matter (up to 15 wt %), and Paleocene clay, and includes the largest metamorphic outcrop in Israel, some 50 sq. km of the Hatrurim area (Figure 2). It consists of a black "baked" chert and of bluish-green "apatitic limestone" (Campanian), overlain by a low-grade metamorphic unit of "baked" oil shale, almost devoid of organic matter, and completely recrystallized multi-colored metamorphic chalks and hydrated calc-silicates. Overlying these are spurrite and larnite marbles, and gehlenite-rich and anorthite-pyroxene hornfelses displaying intermediate to high-temperature metamorphism [9]. The overall section is impregnated by secondary volkonskoite, gypsum and aragonite veins; halite, iron oxides, barite, quartz and uranium mineralizations are substantial. The structural position of metamorphic sequences of the Mottled Zone (Hatrurim Formation) is in the vicinity of strike-slip and oblique faults, beneath and adjacent to the large flexures (Figure 2).

Bentor et al., [10] suggested the internal combustion of bitumen to have caused high-temperature, low-pressure metamorphism as basically an isochemical process. The burning occurred close to the surface in many local foci. The heating was then followed by retrograde processes in the metamorphosed rocks (hydration, carbonation and sulfatization). Unknown are the mechanism responsible for ignition in many local foci and what type of fuel was burnt in the oxidation zone, sometimes at a distance of more than 100 m above the nearest bitumen. Also unknown is what caused recrystallization of the rock-sequence and the secondary mineralization. This hypothesis postulates that cold waters somehow enter a hot (>100°C) rock-sequence which is unlikely since under atmospheric pressure it would immediately vaporize. However, this hypothesis is still supported by some Israeli geologists [11]. Burg mapped the metamorphosed rocks in the Biq'at Hatrurim area, based on correlation between metamorphic rocks and protolith [12]; his (with Heimann) K-Ar dating of the metamorphism

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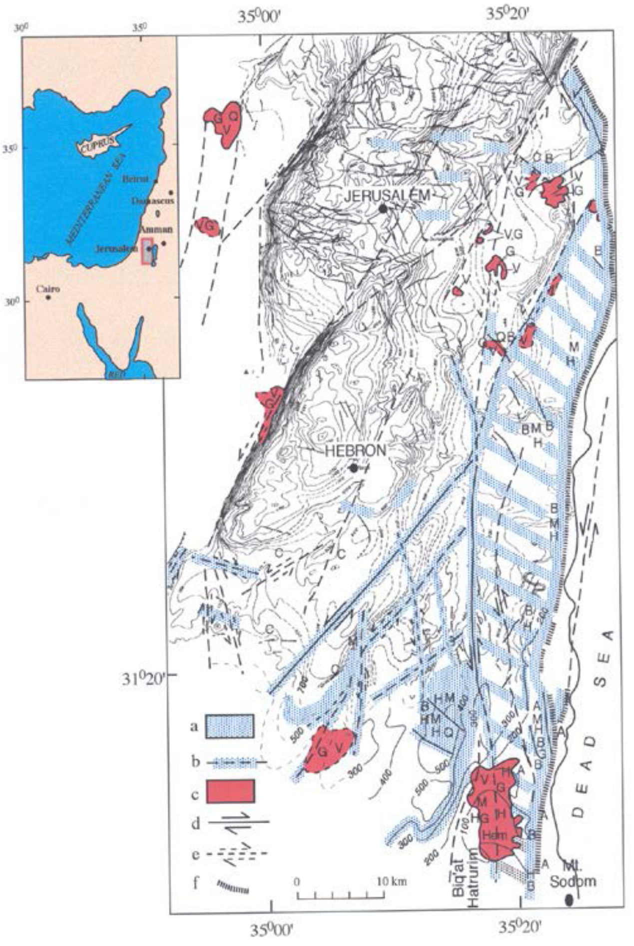

Figure 2: Structural map of central Israel with areas affected by Pliocene-Pleistocene hydrothermal-metasomatic and metamorphic processes (after [7]). Key horizon top Turonian, contours at 50 m. a - area of the most intensive strike-slip faulting, block - rotation, circular dolomite bodies and massive dolomitization along fault-shear zones; b - massive dolomitization along major faults and flexures; c - low to high temperature - low pressure Pliocene metamorphism (Hatrurim Fm.); d - major strike-slip and oblique faults; e - major strike-slip and oblique faults, inferred; f - major Dead Sea fault escarpments. Plio-Pleistocene hydrothermal mineralizations: A - asphalt penetrations; B - barite; C - calcite and G - gypsum (only the large mineralizations shown); H - halite veins; Hem - hematite; M - rare elements and metals; V - volkonskoite. Note: not all of the map area has been geochemically studied.

event yielded a Pliocene age (~3 Ma). Burg has also shown that in numerous cases the burning was clearly focused along cracks, which served as conduit channels; in many localities this occurred 10 to 200 m above the top of bituminous rocks (12). Porat et al. Pleistocene ages dated by ESR are 1.2-1.7 Ma and 0.2 Ma, Gur et al. $^{40}Ar/^{39}Ar$ dating results were 2-4 Ma [13].

The other thermal events in the Pliocene-Pleistocene were more than 100 km^3 scale dolomitization of rocks, from a depth of more than 2 km and up to the surface, with temperatures up to 120°C followed by calcitization-baritization processes, with the temperatures up to 150°C and higher [14]. Gilat [14] proposed that Hatrurim type metamorphism is a hydrothermal metamorphism, a complex process evoked by tectonically introduced overheated fluids, rich in volatile hydrocarbons. These fluids reached the pressure-release point, converted to steam, exploded and caused hydro-fracturing ("hydro-explosions") and rocks-brecciation.

From 2006 to the present Vapnik, Sokol, Novikov, Sharigin, Khesin and others published more than 20 articles on the geology, geomorphology, geochemistry and mineralogy of this formerly "enigmatic" Mottled Zone metamorphism, describing among other findings breccia chimneys, paralavas with the melting temperature about 1400°C and discovered 19 new minerals. They proposed a new hypothesis suggesting a pyrometamorphic process whereby matter with hydrothermal solutions, steam and hydrocarbon gases flow from the deep stratum and combustion takes place in the sub-surface and surface (mud-volcanism, Figure 3) [15]. In proximity to some of the paralava flows they discovered also the earliest Paleolithic tools of prehistoric man made from larnite-bearing rock [16]. These rocks are the strongest and densest rocks in the Levant; field sampling with a 2-kg sledgehammer commonly needed to break them is decisive evidence that the breaking strength required for larnite-bearing rocks is huge. These extreme rock characteristics are supported by the established rock mechanics parameters [16]. Nevertheless, judging from the amount of knapping waste, an enormous amount of axes and adzes was produced, probably over a long period of time.

Earthquake-Impelled Thermobaric-Hydrothermal Explosions as a Cause of Fires

Open space breccias and related caves (Figures 4 and 5) have been recorded in the western Dead Sea area in previously dolomitized Turonian and metamorphosed Senonian - Maastrictian sequences [17], and later on in a Pleistocene conglomerate sequence in the Dead Sea basement. The strata-bound breccias are clearly visible in the road-cuts of the Arad - Dead Sea road, and on the cliffs sub-parallel to the road exposing a dolomitized Turonian sequence. Breccia occurs in runs up to 50 m high and hundreds of meters long. In most of the breccia the very sharp, angular dolomite fragments, from less than 1 mm ("dolomite flour") to tenths of centimeters in size, are loose or cemented by caliche crust, dolomite, calcite and iron oxide (Figure 6). Blocks of these are separated by open or partly filled fractures. Fractures are at times straight, at other times jig-saw, concave or concentric, or radial. At many loci there is a clear concentric arrangement of fragments according to size, flour size in the center, becoming larger toward the periphery. Numerous caves, clearly visible along the same Arad - Dead Sea road in the Arad vicinity, are the result of erosion washing out rock-particles powdered by explosions (Figures 4 and 5). In many cases the close-to-open fracture sides of fragments are "butchered" or look like

Figure 3: Eastward view on the dormant and eroded Hatrurim mud-volcanoes area, southern basin of the Dead Sea and Trans-Jordan mountains in the background.

Figure 4: Small cave development in the hydrothermal explosion chamber about 3 m in diameter (upper right) as seen in the road cut of the Arad – Dead Sea main road, westernmost Hatrurim area. The fractured country rock is epigenetic dolomite, Turonian. Note concentric fractures around the cave, superimposed on systematic tectonic fracturing and the relict of the white non-dolomitized limestone layer beneath the cave.

Figure 5: Erosion taking away flour-size material (center) in one of the explosion chambers in the upper part of the Ye'elim Valley southeast of Arad; epigenetic dolomite, Turonian rock-sequence.

hammered over from the direction of explosion (Figure 7). All breccia described herein is considered to have resulted from hydrothermal explosions and associated fracturing.

Hollow fractures or steam cushions (Figure 8) in the metamorphosed rocks of the Mottled Zone facies exposed farther down the road and in the Pleistocene conglomerate of the Dead Sea basin are dominantly sub-horizontal, and often sub-parallel to the surface. The overlying rocks are intensively brecciated. In the Arad area this breccia is related in space and time to the halite-related mineralizations of trace and noble metals found previously [7,18]. In appearance these are similar to the breccias of "disputable origin", which are typical of the world-famous Mississippi Valley-type and other types of deposits of barite - lead - zinc - uranium - copper and noble metals [19]. Comparative SEM and EDS examination of epigenetic dolomite breccia fragments from natural and man-made explosions show certain similarities in micro-fracturing, which is more intensive than in non-fractured, near-by dolomite (Figure 9). The fractured black chert ("baked chert") from the Hatrurim area contains small particles of carbon soot, possibly left from burning hydrocarbon-gases. Similar particles have also been found in dark-brown patina layers on separated by hollow fractures, dolomite and chert breccia, collected from five different sites outside the Hatrurim area near Arad, Newe Zohar and in the vicinity of 'En Boqeq (Figures 10 and 11).

Hypothesis of hydrothermal metamorphism for the genesis of the Hatrurim pyrometamorphic rock-sequence [14] involved overheated to 120-150°C and even higher temperatures fluids [7,20], rich in

Figure 6: The same area as in Figure 4, epigenetic dolomite brecciated by hydrothermal explosions, very sharp, angular dolomite fragments, from less than 1 mm ("dolomite flour") to tenths of centimeters in size are loose or cemented by caliche crust, dolomite and calcite.

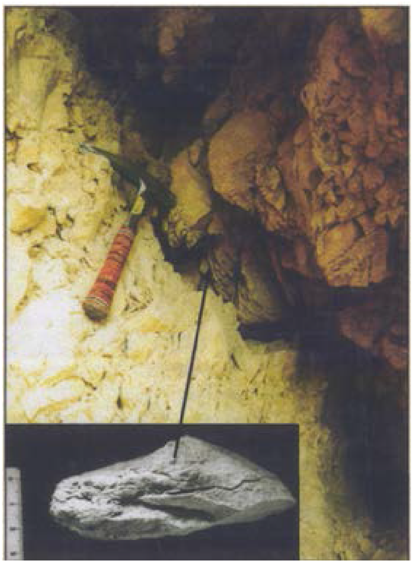

Figure 7: The same area, dolomite rocks "butchered" by hydrothermal explosions along a fracture; seen on the black and white photograph is one of the fragments from beneath the hammer (arrow): note fracture propagation from the center of explosion on its left. Photograph by M. Dvorachek.

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Figure 8: Nonsystematic subhorizontal hollow fractures (blistering) or "steam cushions" in the spurrite metamorphic rocks of the Mottled Zone facies and brecciation above them, caused by hydrothermal explosions, exposed in a quarry in the Hatrurim area. Note E. Vapnic's figure for scale.

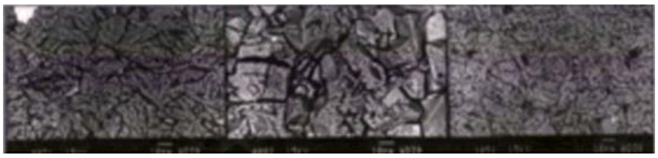

Figure 9: SEM-microphotographs (backscatter), showing microfracturing of epigenetic dolomite fragments, taken from (left to right): (a) center of a man-made explosion (road-construction in the locality of Figure 3); (b) center of the "flower-type" structure (locality of Figure 5) of a natural explosion; (c) the same non-exploded massive dolomite close to the same locality. All SEM graphs and microphotographs by Dvorachek.

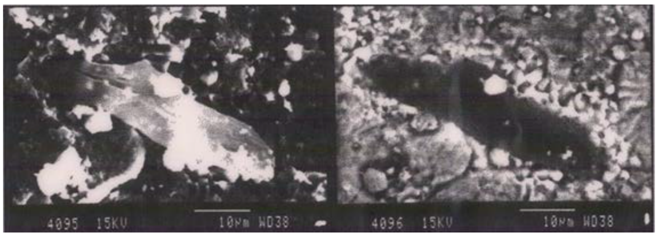

Figure 10: SEM-microphotograph of carbon soot-particle in patina layer above open-space Campanian chert breccia (0.5 km SE of Arad): (4095) SEI, (4096) backscatter.

combustible gases, introduced from the depth of 5-6 kilometers by strike-slip related earthquakes. This kind of pressure reduction takes place when an earthquake opens fractures or when super-pressurized liquids force their way up to a near-surface zone of stress-release. These fluids converted explosively to steam (with corresponding volume increases of up to x1700) somewhere in the chert-bitumen part of the Mottled Zone and caused fracturing, brecciation, combustion of exhausted volatiles and pyrolysis of bitumen. Similar industrial processes, hydraulic fracturing ("fracking") and pyrolysis of oil-shale were used on a commercial scale world-wide in order to fracture shale rocks to release natural gas and convert kerogen into shale oil [e.g. Wikipedia and many hundreds articles in the Internet]. Heated inflammable products of the pyrolysis were expelled through cracks and fissures to the zone of oxidation, where the next stage of spontaneous combustion took place, causing intermediate and high-grade metamorphism close to the rock-surface.

One of the proofs of the possibility of such a speedy rise of liquids is the anomalously-high (up to 40-60 ppm, [7]) concentrations of thorium in the asphalt and halite-gypsum crust beneath active seepages in the ʿEn Boqeq vicinity (Figure 1), on the surface of the 2-3 km thick carbonate sequence (thorium compounds are soluble only in very acid solutions, which are quickly neutralized by calcium carbonates). An evidence of hydrothermal explosions is the presence of the micron Au (Ag, Cu) particles in a brown patina layer on a Campanian chert-fragment from the westernmost Hatrurim area (Figure 12); these particles are absent within the fragment. These may be explained by instant evaporation of hydrothermal solutions sprayed by explosion on the rock-surface; the mineralization may be related to the Au-U hydrothermal mineralization found previously in the lowermost phosphorite layer 1 km south of this patina occurrence [7,18].

Explosions cause very quick pressure changes, from very high to atmospheric, which give rise to pulverization of hydrothermal fluids and the escape of gases; it also lowers the ignition temperatures of

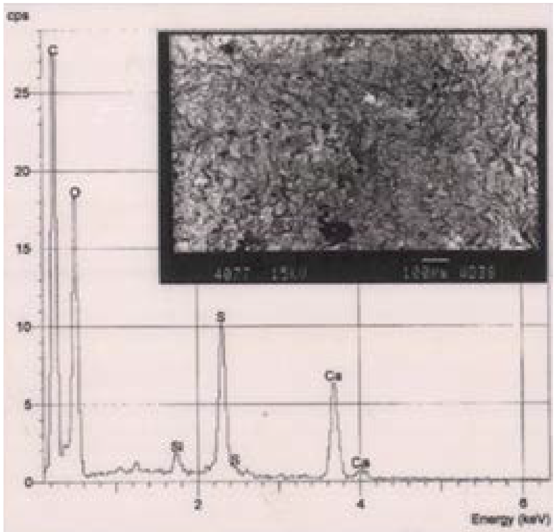

Figure 11: SEM-microphotograph (backscatter) of carbon soot-particles in patina layer above open-space dolomite breccia (Turonian) north of ʿEn-Boqeq near coord. 1838/0708, about 20 m above the main asphalt road.

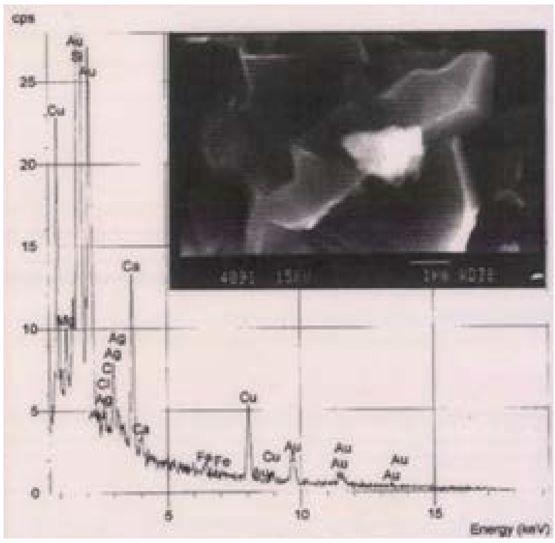

Figure 12: SEM-microphotographs of the Au (Ag, Cu) particle in brown patina layer (rock-sample as in Figure 10); note SEM-EDS-graph in background.

hydrocarbons and hydrogen-sulfide; ionized steam acts as an oxidizer and detergent. Spraying effect of the hydrothermal fluids and ionized steams give rise to conditions whereby any spark could ignite volatiles, thus generating heat, refining organic matter in bitumen and expelling its heated products through cracks, newly made fractures, blisters and steam cushions (Figures 4-8) to the zone of oxidation, where the next stage of spontaneous combustion takes place. Among sources of sparking are piezoelectricity and especially tribo- (frictional-) electricity, resulting from interaction of a high-velocity stream of a wet steam with solids. This electrokinetic phenomena causes formation of drops of liquids with an initial potential of 25-50 mv; evaporation and decrease of drop-size leads to an increase of this potential of up to 1000 v [21]. In the Hatrurim and similar areas the rock-sequence through which the hydrocarbons moved and were expelled could also have served as a chromatographic column. Multi-component enrichment, element redistribution, recrystallization of the rock-sequence and enrichment in hydrothermal/metasomatic mineralization probably occurred during all stages of metamorphism, the process moving from one site to another [14].

Sodom and Gomorrah: Earthquake Creating Fires

Gas seepages on mud-volcanoes frequently caught fire, sometimes burning for many years, as they do now in oil- and gas-rich provinces in Azerbaijan and Persia (Figure 13). The hydrogen-sulfide-bearing ("sulfur smelling") springs are plentiful in the southern Dead Sea coast and their smell is much stronger after earthquakes. Bentor notes, that "before Lavoisier, gases were not conceived as matter. Sulfur does not smell, however hydrogen-sulfide smells, and even today its smell is named sometimes "the smell of sulfur". Fire, not sustained by any perceptible matter, surely was a supernatural event; thus it became an important aspect of Sumerian religion … and the inspiration for the Zoroastrian fire-worship in Persia" [4]. Natural gas seepages and flows from mud-volcanoes in the Hatrurim area frequently caught fire, sometimes heating the rock up to the melting temperatures and generating paralava flows [15], sometimes quietly burning for many years (Figure 13). If the humans who lived near burning mud-volcanoes just a few kilometers above Mt. Sedom in the Hatrurim area, who produced the enormous amount of larnite-stone-tools over a long period of time since the Early Paleolithic period [16], brought dry wood to the burning mud-volcanoes, it would have flamed up and be easy to use as a fire for roasting meat, cooking or guarding the entrance to the living-cave from beasts of prey. It could be that the Hatrurim area and similar to it vicinities of quietly-burning mud-volcanoes were where humans first became efficient in using fire.

The latest stage of the thermobaric-hydrothermal mineralization in the western Dead Sea region, accompanied by explosions and by combustion of hydrocarbons and hydrogen sulfide, cemented the Late Quaternary alluvium beneath the city of Arad (elevation 500 m AMSL) [18]. Combustion of hydrocarbons has left patina containing soot particles (Figures 10 and 11), and there are evidences that the whole area is rich in hydrocarbons. Oil and signs of heavy oil were found in oil-wells southwest of the Dead Sea, including the Hatrurim area. Asphalt seeps are noticeable in fractured Upper Cretaceous rocks and cement the Late Quaternary alluvium in many localities south, west and north of Mt. Sedom ("The Valley of Siddim was dotted with bitumen pits", Gen. 14:10): the Dead Sea has been known as Asphalt Lake since Roman times. A small natural gas deposit is exploited a few kilometers west and northwest of the Hatrurim area, and a gas blowout was recorded close to Mt. Sedom [22]. As we described above, the southern Dead Sea basin area is situated in the intensively fractured central zone of the Dead Sea Transform, a continuation of the great East-African Rift. It is covered by mixed clay and other alluvial fan sediments susceptible to liquefaction, and if liquefied by earthquake it is not a barrier to a flammable flow of gas-liquid-steam-rock-particles, which may be scattered by explosion. The static charging of such a mix-flow, piezoelectric and triboelectric phenomena and sparking resulting from cracking and collision of rocks are natural reasons for the multi-center ignition, effect similar to that of the "vacuum bomb".

It is evident from the regional geology, from the biblical text and historical evidences, that no volcanic eruptions were involved in the Sodom and Gomorrah event; however the fire was. Thus, the famous Greek geographer Strabo, who visited the Dead Sea area somewhere between 20 BC and 15 AD, wrote in his Geography [23] the following: "Many other proofs are produced to show that this country is full of fire. Near Moasada [Masada] are to be seen rugged rocks, bearing the marks of fire; fissures in many places; a soil like ashes; pitch falling in drops from the rocks; rivers boiling up, and emitting a fetid odor to a great distance; dwellings in every direction overthrown; whence we are inclined to believe the common tradition of the natives, that thirteen cities once existed there, the capital of which was Sodom, but that a circuit of about 60 stadia around it escaped uninjured; shocks of earthquakes, however, eruptions of flames and hot springs, containing asphaltus and sulphur, caused the lake to burst its bounds, and the rocks took fire; some of the cities were swallowed up, others were abandoned by such of the inhabitants as were able to make their escape." Basically, Strabo and Captain Fitz Roy (in Introduction) described the same phenomenon….

Strabo also wrote: "It is natural for these phenomena to take place in the middle of the lake, because the source of the fire is in the centre, and the greater part of the asphaltus comes from thence. The bubbling up, however, of the asphaltus is irregular, because the motion of fire, like that of many other vapours, has no order perceptible to observers" [23]. And behold! When earthquakes wake up a mud-volcano, which ejects a huge volume of inflammable gas [e.g., 24] it starts burning high above the earth's surface on the uplifted by its intrusion contact with atmospheric oxygen, and only later on, when flow lessens, the flame ("out of heaven"!) settles down on the rocks. Destructive earthquake and explosions of superheated liquids in the presence of combustible gases remarkably fit the destruction of these cities as described in Genesis, 19:24-28. According to Neev and Emery [22] the event took

Figure 13: Yanar Dag (Fire Mountain) near Baku, Azerbaijan; natural gas combustion and flames on the marl have occurred there for at least 70 years (photograph by E. Vapnik).

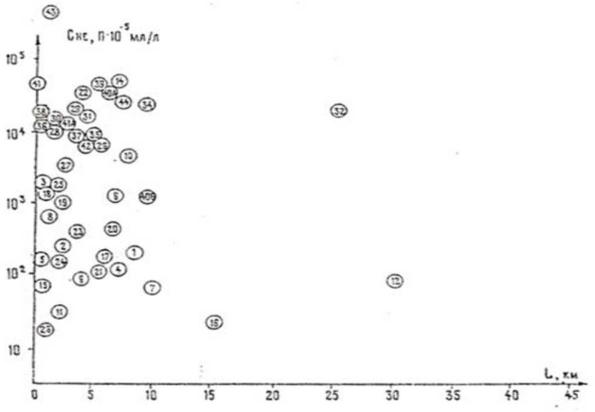

Figure 14: [Some of the former USSR] Nuclear Power Plants (NPP) construction sites on the plot of L (distance from a capable fault, km) versus CHe (helium field intensity, n x 10^{-5} ml/l). NPP names: 1) Armenian, 2) Azerbaijan, 3) South-Ukrainian, 4) Kharkovskaya, 5) Zaporozhskaya, 6) Beloyarskaya, 7) South-Yuralian, 8) Kostromskaya, 9) Kaliniskaya, 10) Odesskaya, 11) Ignalinskaya, 12) Vitebskaya, 13) Chigirinskaya, 14) Voronezhskaya, 15) Volgodonskaya, 16) Minskaya, 17) Belorusskaya, 18 - Moldavskaya, 19) Tatarskaya, 20) Bashkirskaya, 21) Kuybishevskaya, 22) Kolskaya, 23) Archangelskaya, 24) Chernobilskaya, 25) Grigoriepolskaya, 26) Chmelnitskaya, 27) Rovenskaya, 28) Rostovskaya, 29) Bryanskaya, 30) Novo-Voronezhskaya, 31) Kurskaya, 32) Smolenskaya, 33) Volgogradskaya, 34) Permskaya, 35) Ulyanovskaya, 36) Chuvashskaya, 37) Sedovskaya, 38) Primorskaya, 39) Yaroslavskaya, 40A Dimitrovskaya, 40B - Noginskaya, 41A) Povilostskaya, 41B) Liepayskaya, 42) Krasnodarskaya, 43) Gruzinskaya, 44) Balakovskaya, 45) Krimskaya. On the original plot: 40) NPP name is absent, 45) (NPP-Krimskaya) is not shown (from [figure 25 in ref [25] translated from Russian].

place around 4350 BP.

Discussion and Proposals

Can the event similar to that of Sodom and Gomorrah happen again? Yes, in a seismically active area, rich in volatile hydrocarbons and hydrogen-sulfide, especially in an area with mud-volcanoes and strike-slip faulting. It is well known that some of these faults or parts of the fault are often masked by loose sediments or by rivers, which flow along them. And river-water is exactly what engineers look for nuclear power-plant (NPP) cooling systems; that are why NPPs are often situated near active faults. For example, in the former USSR some NPPs were built on active faults, and about 25, on a distance of less than 5 km from them (Figure 14). Capable faults emanate helium, and the best way to record them is mapping helium field intensity [25]. One of results of this mapping was a closure of the Krimskaya NPP, constructed in the Crimea Peninsula on the active South-Azov fault-zone adjacent to mud-volcanoes. It was closed at the beginning of 1990 after protests of the public, which were initiated by geologists [24, pp.159-160].

We underlined herein the role of the major strike-slip faulting because it differs from other types of faulting in its unique long-range connection with the mantle and develops extensive en-echelon systems of branch-faults, thus providing an excellent conduit for a stream of mantle' super-pressured hydrothermal fluids. The probability of the stream generation, its high-velocity and flow-stability depends on the formation of a system of parallel channels (fractures), connecting the depth-source of hydrothermal solutions with the earth-surface; these are easily produced by strike-slip fault-related earthquakes. In this case a well-known effect of pulsation of the steam-water mixture between channels promotes active movements over a long period. Zones of different conductivity in these channels and conforming changes in stream velocity generate cavitations and sound waves (high and low frequency oscillations), whose interference may also produce fracturing and breccia of different orders (on explosive properties of water solutions in volcanic and hydrothermal systems see also [26]). The extension of thermobaric phenomena (volume explosions, local combustions, shock-waves in the air and on the earth- water-surface) may create, in its turn, a nonequilibrium heterogeneous field of stresses and shock waves on the phase boundaries at great depth and produce local zones of depression. These may set off exothermic reactions of decomposition of helium compounds, stable only in high-PT conditions (He-H, He—Si, He-Metals, He-O etc.), and liberation of huge amounts of energy which may trigger a new earthquake "aftershock" [2,3]. It is also well to bear in mind that mud-volcano activity, like every volcano activity world-wide, begins with earthquakes…

The currently accepted theories concerning earthquakes fail to account for a major source of internal energy, accompanied by mantle H- and He-degassing, which is much more suitable for explaining major internal processes of the Earth [2,3]. Contrary to the hypothesis of "any small earthquake… cascading into a large event" [27], we are confident that before an earthquake some monstrous energy must in some way be concentrated at a certain point, in a certain form, in a certain medium, and by some means triggered to explode in a series of cumulative explosions, fitting the biblical, Captain Fitz Roy's [1] and Strabo's [23] descriptions. The main question is how these energy concentrations of planetary scale manifest themselves before a major explosion. Better understanding of those processes will be helpful also in a search for short-term earthquake precursors, and only then will the informed populations are able to evacuate for safety.

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