ARE KIMBERLITE PIPES A KIND OF MACROSCOPIC NUCLEAR TRACKS FORMED IN COLLISION WITH CUDO?

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(Received March 8, 2013; revised version received March 26, 2013)

A new, unorthodox mechanism is proposed to explain the formation of kimberlite pipes supposed to have been formed as the result of cosmic ultra-dense objects (CUDO) passing through the Earth. Moreover, it is proposed that due to such a passage, neutrons produced in nuclear reactions in the plasma formed at the front of passing objects, cause natural elements abundances and their isotopic ratios to change. Thus, to assess our model and hopefully obtain an indirect proof to CUDO class objects existence, we suggest researching such geochemical anomalies in crustal country rocks around kimberlite pipes, as well as in xenoliths embedded in kimberlite materials.

DOI:10.5506/APhysPolB.44.787
PACS numbers: 95.35.+d

1. Introduction

In 1984, Witten [1] proposed the existence of stable, ultradense matter formed from u, d and s quarks. This matter was to be formed in Big Bang and then continued to exist in a form of Dark Matter related mostly with the galactic halo. Soon, it was suggested that such objects

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could penetrate the Earth [2] or other planets, what might be discovered by analysing seismic waves [3, 4]. Such hypothetical objects were termed quark nuggets [5, 6], stranglets [4, 7], nuclearites or preon nuggets [8, 9], and more recently [10] "CUDOs" (Cosmic UltraDense Objects); the latter term nicely carries in Polish the literal meaning of "wonder". However, the existence of macroscopic bodies composed of nuclear or subnuclear matter has not been experimentally confirmed yet. Though massive objects formed from such matter are well known as neutrons (baryons), or hypothetical quark ("strange") stars, still no experimental evidence for such objects in near zero gravitation forces have been reported. However, specific effects related to their hypothetical presence in the Solar System have been already published and discussed [8, 10].

2. Proposed hypothesis

We propose for these geological structures, quite unique on the Earth and known as kimberlite pipes, to be formed on cosmic impact, specifically due to very small, but still macroscopic bodies composed of ultradense (*i.e.* of density range of 10^{14} g/cm^3 or higher) nuclear matter, that is the hypothetical CUDO class objects, passing through the Earth at high speed. Such a material might have been formed instantly upon Big Bang (primordial relicts of early ultra-dense epoch) as it was assumed in the initial Witten's hypothesis [1], or in some other cosmic processes with neutron, quark or preon stars involved [10]. When such objects collide off-centrally, their ultra-strong electromagnetic fields might facilitate spreading out the nuclear matter debris. However, the probability of a direct collision of stars is low. Another process which might be considered is when the tidal forces disrupted a system of two neutron stars approaching the Roche limit, or a fall of a neutron (baryon or quark) star into a black hole. While an accretion disc is formed, some of nuclear matter pieces might escape through relativistic jets in the axial, polar zones of the black hole. Another production mechanisms for such dense pieces of matter were discussed elsewhere [5–11]. The jets containing such dense matter might be crossed once, or few times, by the Solar System rotating around the centre of the Galaxy; as kimberlites dating proved the results tend to group in few clusters, our hypothesis seems to gains grounds. Thus, CUDOs no longer would have to be related with uniform distribution in the Galactic halo, which significantly relieves the main difficulty related to its possible collision with Earth, which in the case of galaxy halo objects seems less troublesome.

When such exotic, strongly bound, massive and ultra-hard, nearly indestructible material collides with the Earth, the globe would behave as an elusive cloud penetrated by a hard projectile. The impacting body would

be likely to go through the entire globe. It would interact with surrounding rocks by shock waves, which in front of their trajectories could turn into plasma material. As the penetration process would occur at speed much higher than the value allowing the produced heat to be distributed beyond the collision track, the process would be nearly adiabatic. Still, the transversal momentum would not be high, and none typical impact crater would be formed. It would rather be similar to a nuclear track formation process enlarged onto a macro scale. Following the passage, heat could be distributed and it would turn rocks adjacent to the "nuclear track" out of the solid phase. Our very rough estimation shows that such a dense object of a mere 1 mm^3 volume and the mass of 10^5 t moving at the speed of 1000 km/s, have enough kinetic energy to heat up to about 1 million K all the material at the surface of 1 m^2 in the cross section and over the distance of 12000 km (*i.e.* across the globe). Both deep crust rock and mantle material are under high pressure and contain lots of volatiles such as CO_2, N_2 and noble gases. As at that time there would no longer be solid rocks above, all the material could rapidly fill up the empty space of such straight, cylindrical transient cavities left by nuclear macro-tracks, making, in turn, space for the mantle material which would be pressed up into just formed kimberlite pipes. It also seems that semi-liquid, brecciated, highly pressurized and gas-charged ultrabasic mantle material would go more easily into freshly emerging "shaft" opened behind the impacting body, than crustal solid rocks that might have no contact with it. At distance closer to the surface, the ascending stream of melt mantle, foam and debris falling into the empty shaft at high speed, would scratch-off and blow-up even more material from its walls, therefore, the adjacent surface would take a typical carrot-like, conical shape. Some surface rock material might fall into the ephemerally open, transient "shaft" and mix with mantle material at depth range of several kilometres. This could explain such striking findings as mantle material and near surface-derived sedimentary rock mixtures, known as xenoliths, with intruded impact-burned pieces of charcoal, or from completely eroded at the surface sedimentary rocks *e.g.* Devonian fossils-rich limestone, which were reported to be found very deep in hypabyssal part of kimberlite pipes surrounded with crystalline country rock in Slave craton [12, 13]. Only very steep, or nearly perpendicular to the penetrated surface, trajectories would produce the open transient shaft, so-called "embryonic pipe" [14] that would be stable enough to get filled with and stretched by the ascending mantle material in hard and subjected to contemporary tectonic extensional stress crustal rocks. For strongly oblique passages, or compressional tectonic regime, the crustal country rocks would immediately collapse into the transient tunnel/gallery and block the mantle material moving toward the surface, preventing kimberlite pipes from being formed. Similar scenarios occur while penetrating soft, unconsolidated

sedimentary rocks, typical for younger orogenic accretionary belts and in ductile, relatively thinner ocean crust. The entire passage event is supposed to form two symmetrical, crustal "scars" at both ends of the passage channel, connected with entry and exit of the body, respectively, still the temperature of the object would carry the major difference.

Following the high speed passage, still a solid-state, firm body can be heated-up to several millions Kelvins. Such an incandescent body and subsequent thermonuclear plasma flare can generate intense photon flux similar to a flash of thermonuclear blast, hot enough to melt soil and convert it into a glassy crust, as well as burn-off all the vegetation cover into charcoal (certainly only in the case of younger Phanerozoic, post-Silurian impact) around the exit end of the tube. It may explain the formation of still puzzling origin of layered tektites *i.e.* Lybian glass and Muong Nong tektites [15–21]. In general, such scenario is similar in some aspects to the hypothesis of a German astrophysicist Kundt [22] on the nature of 1908 Tunguska event interpreted as atypical, abortive, gas- and dust-dominated kimberlite explosion. On the other hand, Rafelski [10] connects the Tunguska event with the CUDO impact. Similar hypothesis for catastrophic expulsions of hot gases and dust from the Earth mantle was suggested under name of Verneshot by Morgan, Reston and Renero [23]. Despite those fossil traces of events, a younger evidence of similar large aerial thermal events was reported from several archaeological sites around the globe, especially for the late mezolith-early neolith epoch [24].

Moreover, at least one of the related events was observed, *i.e.* puncturing the Earth in the 1990s by pieces of super dense matter, red blood-cell sized, which on the basis of seismic analysis was dated to November 23, 1993 [25].

3. Basic geological data on kimberlite pipes and existing models

The kimberlite pipes are elongated, usually vertical, well-like geological structures very narrow at depth. Despite penetrating the whole crust they measure only a few, or dozens of meters in diameter and are filled with brecciated Earth mantle derived material [26] including diamond crystals. Though kimberlites have been subjected to extensive studies [27–38], still the origin of kimberlite pipes, and their emplacement mechanism remain enigmatic. A classic model of Vesperman and Schmincke [39] provides them as formed by melting the Earth crust rocks by a "needle" of hot mantle material. The weakness of this mechanism lies in unspecified heat production mechanism for incredible energetic expenses inevitable for fast penetration of hundreds kilometres of relatively cold, solid, hard crystalline rocks of stable Precambrian platforms, *i.e.* typical geotectonic position for majority of kimberlite pipes. Moreover, it seems to violate the thermodynamics princi-

ples: the dissipation of heat should stop the needle piercing upward the crust even if the process has been started. The hypothetical syn-emplacement, intensive and localized generation of heat in small portion of mantle materials with generally low concentrations of radionuclides, is also unlikely. Due to the weakness of the classic model, an alternative model was proposed, which includes crust piercing with gaseous CO_2 rich eruption from the mantle [26]. The initial stage of such an eruption was questioned [36]. Recently, Skinner [40] presented and discussed three new alternative models, but they still display similar difficulties. Notwithstanding, we propose another, completely different initial mechanism which might have led to the emplacement and formation of kimberite pipes, and is similar to that proposed by eruption from the mantle but caused by impact.

4. Proposed verification of the hypothesis

In our hypothesis, nuclear reaction (and likely even fusion) would happen while migrating in front of the object hot plasma [41] formed from vaporised rock. Neutrons produced in the plasma penetrate and react in the undisturbed host rock. Their flux and spectrum will be a function of the distance from the pipe. Some activation and fission are supposed to take place in those country rocks (and less in xenoliths, which are usually considered to witness the formation process [42]). This is a proposed signature of our model. The isotopic ratio in the rim of crustal country rocks surrounding the kimberlite pipe deserves special consideration. Due to nuclear activation processes, it should differ from the typical values, and the difference should decrease with the distance from the axis of the kimberlite pipe. Quite contrary to that, the mantle material which fills the kimberlite pipe shall display unusual isotopic ratios in much smaller scale. Many isotopic studies were carried out for kimberlites, however the researchers tended to focus rather on the ultrabasic kimberlite rocks [43–46], than on the kimberlite pipes walls, which in our model are definitely much more interesting as witnesses of the cosmic impact. Interestingly enough, some papers reveal very unusual isotopic ratios that are difficult to explain within the widely popular concepts of isotopic fractionation in nature [47]. Additionally, some minerals present in kimberlite pipe walls shall preserve traces of wave shock acts. Another signature for the proposed kimberlite formation scenario are magnetic anomalies, highly expectable to be observed in kimberlite walls, likely to result from polarization due to hot plasma in motion.

The verification of the hypothesis presented here, if positive, would explain the nature of kimberlite pipes formation, provide indirect prove to the existence of pure nuclear or even sub-nuclear matter on the macroscopic scale, and hopefully produce at least rough estimation of its parameters and

the frequency of its occurrence, thus, also of the density in the Galaxy. It would mean grave consequences for the general knowledge on the Universe, and even on the basic question regarding the nature of Dark Matter [48–50]. Eventually, all the chronology of kimberites formation based on the isotopic studies would need to be revised, as additional activation corrections would have to be applied to $^{87}Rb/^{87}Sr$, $^{40}K/^{40}Ar$, U/Th/Pb, and any other isotopic systems used for dating.

5. Conclusions

The proposed mechanism for kimberlite pipes formation is based on the well known physical phenomena and generally accepted natural laws. At present, it is of a merely working value, though it enabled us to explain several observed properties of kimberlites, such as their strange geometry regarding size, shape and proportions, or nearly perpendicular orientation to the surface, as well as brecciated but not melted mantle-derived fill, mixed with surface rocks observed in some sites and other unexpected difficulties which typical isotopic methods failed to solve. To verify the assumed process, we suggest investigating anomalies in the isotopic ratio within the crustal country rocks surrounding the kimberlites, which shall change with the distance from the kimberlite pipe axis. Shall verification of our hypothesis prove positive, indirect proof of the existence of CUDO class objects would be provided.

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