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COMMENT ON DIAMOND GENESIS, ORE DEPOSITS AND RING STRUCTURES

by

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1. *Introduction*

In the recent paper VESANEN and TEISSEYRE (1982) have indicated that a dense mosaic of ring structures is blanketing the Earth's surface. A plausible interpretation has been related to meteoritic bombardments. Some consideration on high pressure and high velocity physics related to the impact processes led us to the conclusion that ring structures of impact are connected with the sites where ore deposits and even diamonds have found their genesis.

In this paper we are trying to make an approach to the question how and where diamonds would have been created within the processes of meteorite impact. The location of diamond deposit in a crater topography is illustrated by the cartographic analysis of one ring structure having diamond deposits. Some other examples are related to the ore deposits.

2. *Diamond genesis*

The very recent books (WILSON, 1982; MAILLARD, 1980; FIELD, 1979), summarizing the state of knowledge about diamonds until the present in this large field and during the long history of diamonds, indicate that although many theories about the genesis of diamond have been developed, none of them has provided any definite answer as to how and where diamonds originate. However, it is known in certain that the crystallisation takes place under very high pressure, about 70 000 kg/cm^2, and temperature, about 2 000 °C. Such conditions exist in

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nature only at a depth of about 200 km beneath the Earth's surface. However, when a great meteorite strikes the planet, the local conditions may be favourable for such crystallisation during a certain time interval. It is also commonly recognized that diamonds are found in the volcanic rock kimberlite. It was not considered until now whether kimberlites could be related to impact structures, but we shall at least assume that they could be related to the ring structures.

3. *Diamond genesis and impact physics*

As described in our previous paper (VESANEN and TEISSEYRE, 1982), the laboratory experiments of the impact cratering process have been mainly simulated with explosives or by impacts against solid materials. The nature of impact has been just a'priori limited to brittle fracturing.

SHOEMAKER (1960) considered a shock mechanism of the impact process, admitting also a hydrodynamic stage of flow in the target material when the velocity is sufficiently high. A similar conclusion can be found in the paper by KING (1976). A more advanced study has been presented by MELOSH (1980). However, all these papers do not explain the very first moment of the penetration process.

In our cited paper we have come to the conclusion that an improved model of impact process should be prepared. Such a model, describing a high velocity impact, shall take into account a kind of »cutting» of the target material when a meteorite hits, fuses and penetrates inside it, its bulk kinetic energy being subsequently converted into heat, material evaporation and into shock reaction waves. The reaction waves are the generalized shock waves (HANYGA, 1973) related to phase transformations which include both the transition to a new lattice configuration as well as the melting process. A high pressure shock waves can in particular overpass the conditions related to a graphit-diamond equilibrium curve – of course, in the suitable conditions.

The impact process may be thus divided into a cutting stage, understood as a forced supersonic crack propagation, and a shock reaction stage followed by a hydrodynamic flow of a highly heated material from below, *i.e.* from a meteorite »oven» back to the surface. The consecutive stages are related to material evaporation, formation of cracks and fissures and to a visco-plastic response ending with the permanent deformations. These deformations can be well modelled by a visco-plastic material response (VESANEN and TEISSEYRE, 1982). However, a more deep, realistic model shall include phase transformations processes inside a target material. Thus, a target response to impact shall be supplemented by melting phase transitions. Due to geometry of shock reaction waves we may expect that there will be some places where shock pressure effects are multiplied, roughly speaking, due to interference phenomena. These places could be interesting from the point of view of a genesis of ores.

Basing on this new theoretical background of the proposed impact mechanism we can try to establish some geometrical relations, using the known impact crater sites or looking in detail after some ring structures. One of such relations was already discussed in the cited paper; it concerns a relation between the inner crater (ring) dimension and the distance to the ore deposits. Quite another relation could join the sites of main shock pressure effects (*i.e.* diamond sites) with the parameters describing the impact structures. A proper relation between the high temperature regimé and the shock pressure effects shall be studied in a more detailed way in order to establish the concentration of reaction wave effects and thus a possible places of the interesting phase transformation sites.

A different theory relating the impact process to the induced volcanic eruption has been presented by SCHWARCZ (1973). Probably both mechanisms could be important for the ore genesis. In any case, however, a role of impact remains as a primary event.

Here we shall also take into account the geometry of the impact path, especially its inclination to the target surface. This makes a problem non-symmetric in respect to the ring structure.

However, part of the method described concerns the general feature of the ring structures, independently of their nature. We are also using here a topographic analysis based on discrimination of structures due to their elevations and trends of the surface inclination.

4. *Diamond deposits and topography of meteorite crater*

Assuming what is said above about the diamond genesis, the diamonds should be found in some areas related to meteorite crater. The kimberlite pipes should be located in some places within the inner ring structure existing around the entering path of the meteorite. If erosion has taken place, diamonds should be found in the alluvial deposits, but still inside the ring structure or, in the river beds running through or from the structure.

The kimberlite pipes have been explained to be lava eruptions of relatively small volcanoes. The diameters of the pipes are varying from two to a few hundred meters only, and the volcanoes disappeared completely, as at least none has been identified yet. According to our theory the kimberlite pipes would be part of the ejectus.

Many difficulties are on one's way when trying to make scientific approach to the problem. When we tried to study certain diamond deposit areas in nature or on the maps, it turned out to be more than difficult: 1) the areas for diamond prospecting are completely closed from outsiders, 2) the good topographic maps are highly secret and not available, especially because of military reasons, and 3) a private scientist cannot have the resources for the large-scale field work needed.

During a private visit to Brazil, it was possible, however, to have a chance to get a permission to visit one diamond prospecting place and another to observe the crater area from its rim. Besides, the topographic map (1:100 000) of the whole area was available, but unfortunately not until after the trip.

One of these two prospecting diamond places was the important Tejucana Mine, on the Juquitinhonha river. There was a chance to see washing of diamonds by a large dredgin machine. But, there was no chance to study the topography of the area, nor to see any local research material, maps, etc. Also the above-mentioned map was quite unsatisfactory for this mine, because most of the corresponding ring structure remained outside it. The other diamond prospecting place, called here the »Diamantina-South», was not possible to reach again because of the poor road conditions. It was possible to check the crater area from the rim by eye only, when traveling along the roads following the rim zone. Due to these limitations it was not possible to do more than to reach the very general conclusion that the areas of deposits do locate near the central part of the structure.

As a general observation it should be pointed out that our map, »Diamantina – Carta do Brazil – Esc. 1:100 000 – Folha SE-23-Z-A-III», is full of ring structures. There are also a few other diamond prospecting places marked on the map but we did not know about them during our visit to Diamantina.

As mentioned before, only the second of the known diamond washing places, the Diamantina-South, is located completely on the map. According to the coordinates used in the map the limits of the area to be examined are about 6_{40}–6_{50} and 79_{68}–79_{80} (Fig. 1).

To illustrate the topography of the ring structure Diamantina-South, the first important fact to be pointed out is that the whole structure seems to be slightly inclined down towards the east. Therefore, the contour line of 1400 m in the western part of the structure and 1150 m in the eastern part were chosen to illustrate the crater rim, and the contour lines of 1250 m in the west 1100 m in the east were correspondingly chosen to illustrate the crater bowl. The bowl is strikingly hearth shaped, typical for an impact crater (VESANEN and TEISSEYRE, 1982); on both sides of the characteristic »penisula» there are deep and narrow

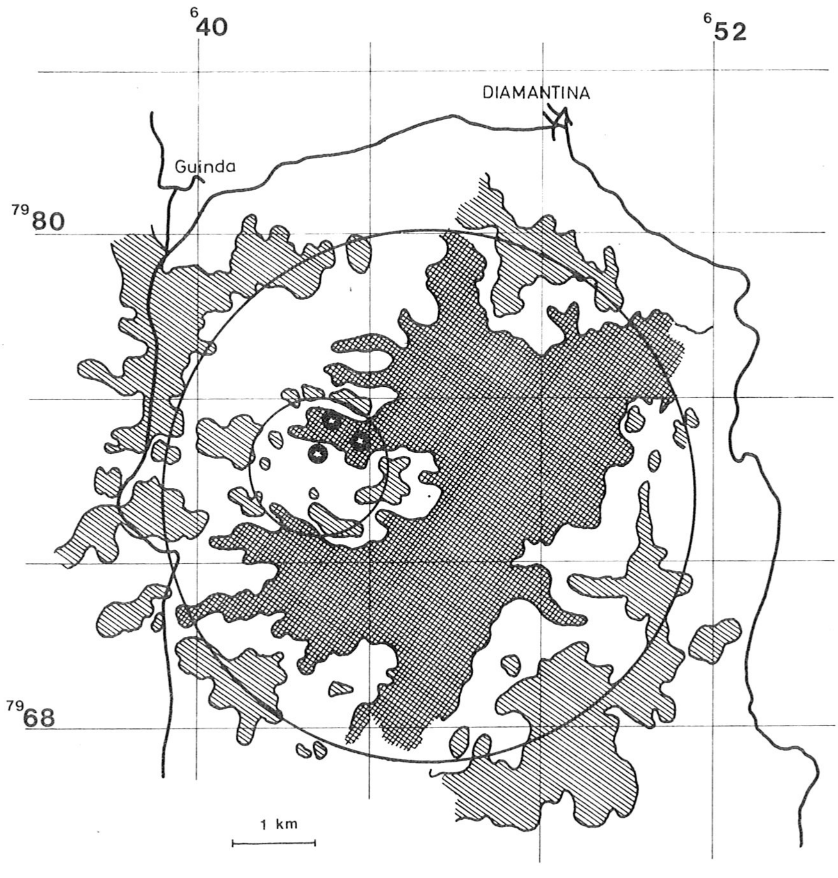

Fig. 1. The topography of the ring structure Diamantina-South. The crater rim has a diameter of about 12–13 km, the outer circle drawn in the figure, and the smaller ring structure developed around the entering path of the meteorite has a diameter of about 3.5 km. The bowl of the crater has a typical heart shaped form. The diamond deposits, indicated on the original map, are marked by white star on black, and are locating inside of the smaller ring structure, in the ejectus area; the original deposits are not found but the mother rock of diamonds must be located also inside of the circle. Different hatchings relate to areas discriminated by their elevation.

trenches with rivers. On the peninsula area there is the entering path of the meteorite; in the figure the corresponding inner ring structure is also shaded, and the elevation of these higher points here are over 1350 meters.

The ring structure Diamantina-South is thus according to its topography a typical product of meteorite impact.

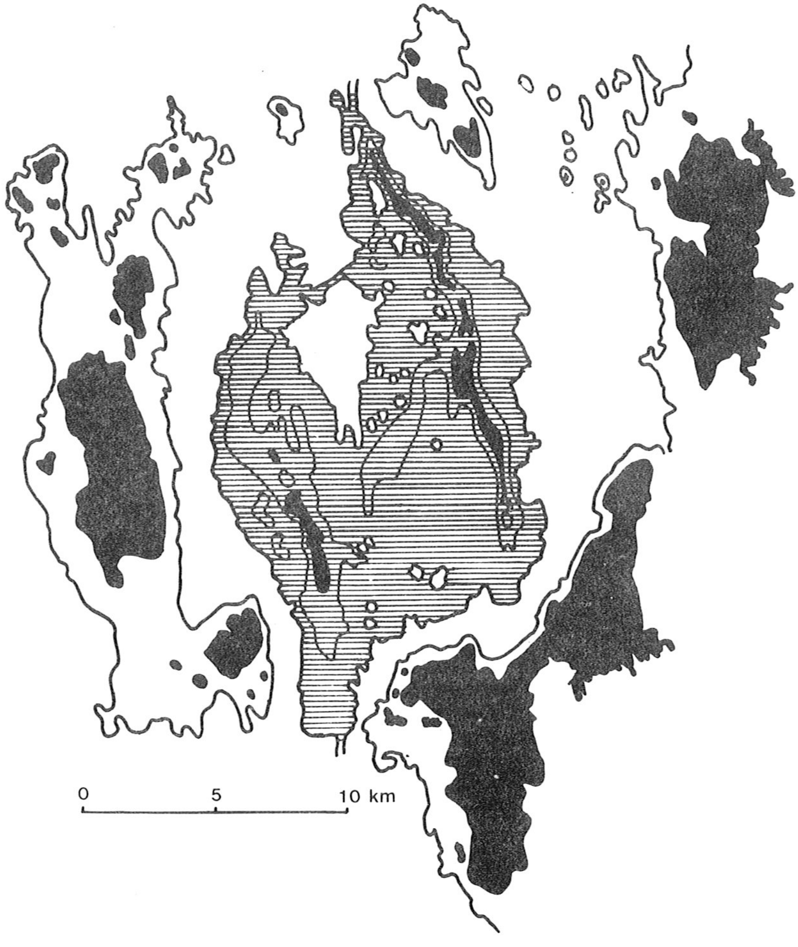

Fig. 2. The topography of the Lappajärvi impact crater in Finland – a typical prototype of the continental crater; heart shaped bowl formed by the lake and the deep trenches on both side of the the central ridge. Different hatchings indicate areas contoured by the height or depth iso-lines.

For comparison and for better demonstration here, meteorite crater Lappajärvi in Finland is shown in Fig. 2 and an another ring structure, the Åva ring in the south-western archipelago in Fig. 3. The detailed geological study of the Lappajärvi crater has been made by LEHTINEN (1976) and of the Åva ring structure by KAITARO (1953). The analogy of the shape and topology of all these three ring structures is real. Similarity can be adequately explained by the same process acting in both cases; the meteorite impact.

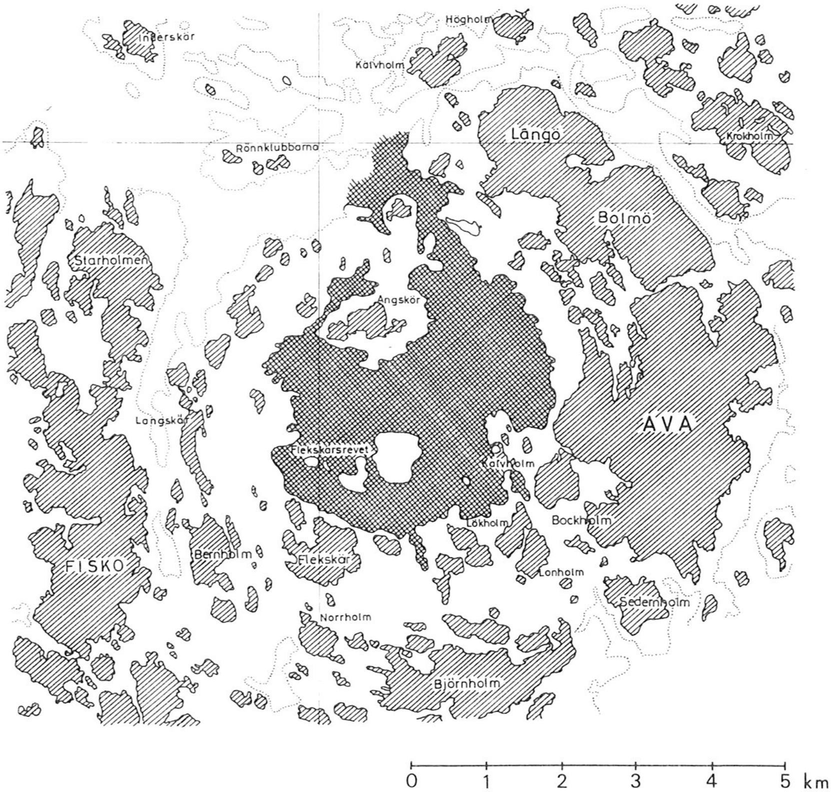

Fig. 3. The Åva ring structure in the archipelago southwestern Finland; the bottom topography of the structure has the typical heart shaped form of the impact crater depression, with the deep trenches on the both side of the central elevation. Different hatchings indicate areas contoured by the height or depth isolines.

In the area of the Diamantina-South ring structure three diamond washing places, given in the original map, are marked in the figure with asterisks: all are located inside of the inner ring structure. The diameter of the Diamantina-South ring structure is about 12–13 kilometers and the inner ring, corresponding the entering path of meteorite, is about 3.5 kilometers. The correlation between these two diameters is in good agreement with the preliminary results obtained from the different ring structures (VESANEN, TEISSEYRE, 1980); this relation will be reconsidered in the next paragraph.

5. *Ore deposits and ring structure*

Already in our previous paper (VESANEN and TEISSEYRE, 1982) we presented the relation between the inner ring diameter d and the distance O from the center of this ring to the ore deposit for each structure considered. Presently a wider collection of data has confirms this preliminary result $d/O \simeq 1/3$.

An another important relation between the diameters of the inner ring d and the outer ring D is presented in Fig. 4; the corresponding ratio amounts approximately to 0.25, $d/D \simeq 1/4$. This relation has been checked up to the diameter $D \leqslant 1200$ km. The diameters of the inner and outer ring of the Hughton impact structure, Canada, equal respectively to 3.5–5.5 km and 20.5 km (ROBERTSON and SWEENEY, 1983) are in the complete agreement with our result.

We believe that further studies might improve these relations and explain some deviations which are surely influenced by the other parameters, like impact velocity, etc.

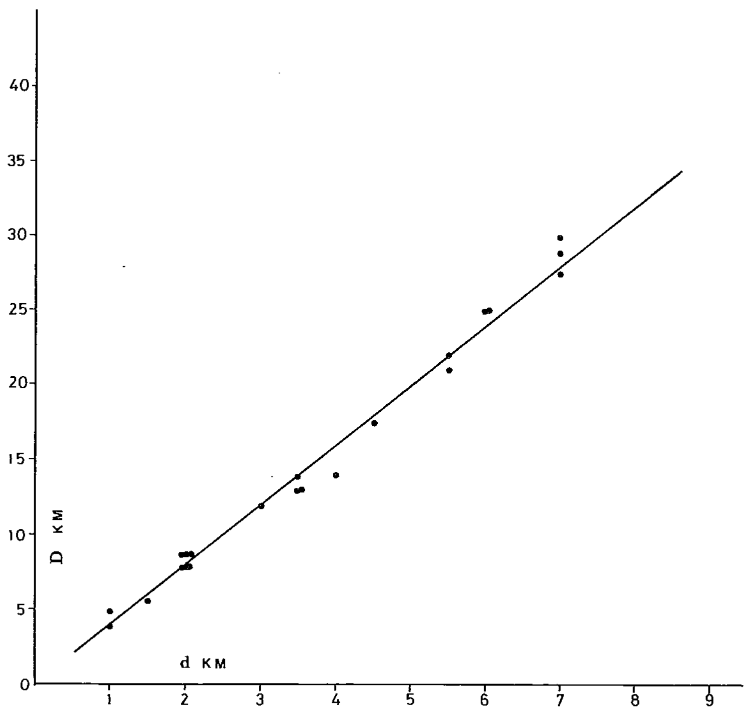

Fig. 4. Relation between the outer ring diameters and the inner ones.

6. *Concluding remarks*

Although it has been possible to demonstrate only one ring structure with diamonds, one cannot deny its support to the thesis of this paper. For a consideration it should be pointed out that none of the other diamond washing places, present at the original map available, has any contradiction to the theory either. Also the generally known diamond deposit areas in different parts of the world seem to indicate that the deposits would be related to ring structures.

To illustrate the extremely laborious and costly searching for the new diamond mining places, we would like to cite here one of the methods discussed in the book edited by MAILLARD (1980): »Although each prospecting campaign is unique, if only because the physical setting varies, the primary operation is always a search for kimberlite minerals on alluvial or eluvial terrain. Once this is done, large-scale reconnaissance makes it possible during the so-called strategic phase to select from regions extending over tens of thousands of square miles the few thousand in which the search should be intensified. Often kimberlites are discovered solely by gradually intesifying the search in a decreasing area, but more frequently concentrating the search results only in isolating an area of a few square miles. Other techniques must then be used to locate the kimberlite itself. This is the »testical» phase, in which geophysics incontestably plays the most important role shallow soil samples are taken and test holes are dug. Then comes the »moment of truth», when the weathered kimberlite is washed to discover whether it contains diamonds or not».

We do believe that our theory discussed in this article will be able to give a useful method for isolating the search for kimberlites to a reasonably small areas – and, which is important, it can be done at the beginning of the search, not at the end.

We have also demonstrated some relations between the ore deposits and the geometry of the ring structures.

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REFERENCES

FIELD, J.E., edited by, 1979: *The properties of Diamond,* Acad. Press, London, New York, San Fransisco, 674 pp.

HANYGA, A., 1973: Thermodynamics and mechanical theory of rapid transformations in the Earth's interior, *Publ. Inst. Geophys. Pol. Ac. Sci.,* **64**, 146 pp.

KAITARO, S., 1953: Geologic structure of the late Pre-Cambrian intrusives in the Åva area, Åland Islands; *Bull. Comm. Geol. Finlande,* **162**, 72 pp.

KING, E.A., 1976: *Space Geology,* J. Wiley and Sons, Inc., New York, London, Toronto, Sydney.

LEHTINEN, M., 1976: Lake Lappajärvi, a meteorite impact site in western Finland; *Geol. Surv. Fin. Bull.,* **282**, 99 pp.

MAILLARD, R., Editor-in-Chief, 1980: *Diamonds, myth, magic and reality;* Crown Publ., Inc., New York, 287 pp.

MELOSH, J.H., 1980: Cratering mechanics – observational, experimental and theoretical; *Ann. Rev. Earth Planet. Sci.,* **8**, 65–93.

ROBERTSON, B.P. and J.F. SWEENEY, 1983: Haughton impact structure: structural and morphological aspects; *Can. J. Earth Sci.,* **20**, 1134–1151.

SCHWARCZ, H.P., 1964: The origin of diamonds in drift of the north central United states; *Jour. Geology,* **73**, 657–663.

SHOEMAKER, E.M., 1960: Penetration mechanics of high velocity meteorites, illustrated by Meteor Crater, Arizona; *Int. Geol. Congress, XXI, 1960, Copenhagen,* 418–434.

VESANEN, E. and R. TEISSEYRE, 1982: A dense crater mosaic as an element of the Earth's topography; *Boll. Geof. Teor. Appl., XXIV,* **95**, 223–237.

WILSON, A.N., 1982: *Diamonds from birth to eternity;* Gemmological Inst. of America, Santa Monica, Cal. 450 pp.