

A Re-Examination of the Craters in the Faugeres-Cabrerolles Region of Southern France*

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Abstract. Five of the six known craters in the vicinity of Cabrerolles and Faugeres, ranging in diameter from 200 to 55m were examined on the ground while additional studies of the same craters were made on aerial photographs. The topography of the five craters and their relationship with their surroundings suggested a relatively recent origin.

A comparison was made of these craters with others of recent origin whose formation by meteorite impact was regarded as substantially beyond doubt. All of the comparison craters (including the Barringer Crater, diameter 1.3 km, and the Kaali-jarv Crater in Estonia, diameter 200 m) showed the phenomena of raised rims and uplifted strata around their edges so clearly as to suggest a definite diagnostic feature. Since no indication of raised rims or radially uptilted strata was found in any of the five French craters it seems justifiable to doubt that any of these interesting features was formed by meteorite impact.

I. INTRODUCTION

Several craters in the south of France near the towns of Faugeres and Cabrerolles have been described by Gèze and Cailleux (1950) and by Janssen (1951) who attributed to them a meteorite impact origin on the basis of their circular forms, considerable depth and the absence of a satisfactory alternative explanation. Recently the impact origin of these craters has been called in question mainly on the basis of magnetic observations which failed to confirm a magnetic anomaly

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reported by the earlier observers (private communication).* Since I was travelling in Europe in the summer of 1962 with the object of studying meteorite impact phenomena, an examination of the above craters was included in my itinerary and this study was carried out in company with Mr. R. G. Madill, chief of the Division of Geomagnetism of the Dominion Observatory. Exceedingly valuable assistance was given by Professor J. Coulomb, Director of the Centre Nationale de la Recherche Scientifique and Professor E. Thellier, Director of the Institut de Physique du Globe of the University of Paris. Through their kindness, automobile transportation to the south of France was provided with the aid of Mr. Albert Segons, a geophysicist of the Observatoire Parc St. Maur who joined the party giving invaluable assistance as guide, interpreter and scientific adviser.

II. CRITERIA FOR THE IDENTIFICATION OF METEORITE CRATERS

There appear to be three main criteria for the identification of meteorite craters:

1. The appearance of nickel-iron meteorites in and around the crater, some of which may be located by magnetic survey methods;
2. A study of the crater profiles which, for a recent crater, are very distinctive and only duplicated by craters produced by very large explosive charges;
3. The characteristic sub-surface rock shatter pattern produced by a heavy impact or explosion (Beals, Innes and Rottenberg 1960, 1963).

Since in the present instance (1) was being studied by Messrs. Madill and Segons and (3) required the use of expensive trenching or diamond drilling equipment which was not available, I devoted my attention to (2) and made as careful a study as possible of the crater profiles.

Fortunately, for a study of this kind, there is available a number of well authenticated examples, and a study of the literature of craters leaves little doubt that their forms are unique and diagnostic. The

*Recent studies suggest that there is no single clear-cut and unambiguous interpretation of magnetic anomalies associated with meteorite craters. For a non-metallic meteorite the disalignment of magnetic poles in the country rock by the shock of impact may result in a smaller and less disturbed field than in the surrounding areas. (Beals, Innes and Rottenberg 1963, *The Solar System* Vol. IV, p. 255, University of Chicago Press.)

type craters are (1) The Barringer Crater (Barringer 1924 and Shoemaker 1960) in Arizona, U. S. A., (2) The Wolf Creek Crater in Australia (Guppy and Matheson 1950, Reeves and Chalmers 1949), (3) The Chubb Crater in Ungava (Meen 1950, Currie and Dence 1962), and (4) The Kaalijarv Crater in Osel Island, Estonia (Reinwald 1928, 1939).

All of these craters, which cover a range in diameter from 3,200 m to 110 m, exhibit the following characteristic features which, taken as a whole, appear not to be duplicated by any other natural process. They are circular depressions with raised edges having generally different proportions from ordinary volcanic cones and calderas. The central part of the crater dips below while the rim of the crater is raised above the surrounding plain so that, on balance (in contradistinction to volcanoes) there is neither addition to, nor subtraction from the general topography. The raised rim is due in part to the ejection of debris by the impact and in part to the up-arching of surrounding rock by the force of compression. In sedimentary rock this phenomenon is very conspicuous. The strata are uplifted around the crater's edge so that they dip radially away from the center. A few cases are known where they stand vertically or are actually overturned; these phenomena are particularly well marked in the well known Barringer Crater in Arizona. Since such radial configurations are not observed in the case of volcanoes or calderas or indeed in any other natural landscape features, it appears logical to utilize them for crater identification and indeed to question the identification of recent undamaged craters which do not have them.

III. APPLICATION OF CRITERIA TO CABREROLLES-FAUGERES CRATERS

(1) Le Clot. The above-mentioned criteria were applied to the French craters, first to Le Clot, the largest of the group, 200 m in diameter, almost twice the size of the Kaalijarv crater of Estonia which has a diameter of 110 m. The relation of Le Clot to the neighboring topography leaves little doubt that it is of relatively recent origin. It is situated in a ravine whose axis is in a north-south direction and which by analogy with neighboring similar features, could hardly have existed in its present form if its origin had been subsequent to that of the crater. The crater appears to have suffered little erosion. There are abundant rock outcrops on its inner slopes and a path around most of its rim (part of the rim is included in vineyards) makes a study of this part of the topography relatively easy.

A study of the contour map of Gèze and Cailleux and a preliminary look at a stereoscopic pair of aerial photographs gave little or no indication of a raised rim, but the possibility was considered that such

a feature might have been concealed by the relatively complicated neighboring topography. A study on the spot left no reasonable doubt that there was no indication of any raised rim in connection with this crater. The diagrams and formulae of Baldwin (1949) suggest that a crater of this size should have a rim rising 15 m above the surrounding plain. While the surrounding area is far from being a plain, a rim of this magnitude could scarcely escape detection even on a rather casual inspection. Actually there are two relatively flat areas, one to the west and one to the south of the crater where a rim of even one or two meters would be conspicuous, but there is no indication whatever of any elevation of this kind. Subsequent to the visit to France, through the kindness of Mr. Segons, I secured stereoscopic aerial photographic pairs for all the craters investigated. With this material it was possible to make careful and detailed studies of Le Clot with high magnification, making use of a stereoscope of excellent optical quality. The result of these studies was entirely negative insofar as a raised rim was concerned. Moreover, I am convinced, on the basis of seven years of experience in the study of aerial photographs, that a good stereoscopic pair of photographs will give a better and more unambiguous indication of the presence or absence of a raised rim than an examination on the ground. It now appears possible, therefore, to say with reasonable certainty that there is no raised rim associated with the Le Clot crater.

With regard to the presence of up-arched strata associated with Le Clot, again the result appears to be completely negative. The crater is located in sedimentary rock designated as schists and carboniferous sandstone by Gèze and Cailleux. There appears to be a general dip of the strata in a south-westerly direction. While this produces strata dipping away from the center of the crater on the southwest side, the opposite is the case on the northeast. In spite of abundant outcrops which made observations easy, I was not able to find any indication of radial symmetry associated with the attitudes of sedimentary rocks making up the walls of this crater.* While it would be very desirable to have this matter checked by a trained geologist, the likelihood of any other conclusion is remote, and the absence of this diagnostic feature raises doubts as to the meteoritic origin of this crater.

(2) Crater 300 m Southeast of the Gare de Faugeres. This crater, though smaller than Le Clot, is still of reasonably impressive size (55 m in diameter and 23 m in depth). Hence, if it were due to the impact of a meteorite, the presence of a raised rim and of outward dipping strata should be clearly seen. Here again, rock outcrops are reasonably numerous while the terrain surrounding the crater is not

*The Kaalijarv Crater, although only about half the size of Le Clot, shows these effects clearly.

so rough as to make the search for a raised rim too difficult. The rim was studied first on aerial photographs. It was immediately noted that the crater was located near the top of a reasonably symmetrical small hill which gave the crater on the aerial photographs, an appearance slightly suggestive of a volcano. Investigation on the spot did little to confirm the very slight similarity to a volcanic form. The effect of the stereoscope was to exaggerate the topographic contrast and it was found that actually there was enough flattish land to the north and east of the crater to make a search for a raised rim reasonably definitive. While farmers in the vicinity had used the edge of the crater to pile rocks removed from neighboring vineyards, giving the crater a somewhat artificial raised rim, no evidence whatever was found for a true raised rim of the kind associated with a typical meteorite crater. Subsequent studies of aerial photographs, after the ground examination had taken place, confirmed this conclusion. Insofar as it was possible from the photographs to judge the probable pre-crater topography, no evidence was seen of any elevated rim surrounding the crater. The topography was, in fact, more suggestive of a depression formed by collapse with a rather sharp drop into the crater and no evidence of any disturbance extending outward from the edge.

The negative evidence in the matter of a raised rim was paralleled by the lack of any indication of radially symmetrical outward dips of the strata of which the crater walls were composed. Rock outcrops were numerous; if there had been a symmetrical system of outward dips around the crater it is difficult to see how they could have escaped detection. Actually the only dips observed appeared to be regional with no evidence of any relationship to the crater form. The regional dips had a general southerly direction and moderate inclination and appeared to be common to the crater as a whole.

(3) The Two Craters Immediately West of the Town of Faugeres. The two circular or near-circular depressions of 72 m and 57 m diameter with depths of the order of 20 m are located in an area where fairly drastic artificial changes may have been made in the terrain. The ruins of an old castle overlook the northernmost of the two craters, while the southern one has been filled in with earth and used to some extent for agriculture. The fact that the northern crater of the two is used as the town dump has interfered with its value as a source of scientific data. Nevertheless, there are some rock outcrops (of limestone) on the southeast wall which show a south-westerly dip but outcrops in other sectors are lacking. No evidence was found either for a raised rim or for strata dipping radially away from the center.

Any outcrops originally present in the southern of the two craters have been covered over by soil and alluvium, probably by both natural and artificial agencies. The stratified rock in the immediate vicinity

of this crater is of limestone and shows no unusual or diagnostic orientation of its bedding planes. No evidence of a raised rim was seen.

(4) Crater 1 km Northeast of Faugeres. This is a rather impressive crater about 60 m in diameter and 20 km deep but is so heavily grown up with trees and shrubs as to make investigation difficult. There are extensive outcrops on the east side of the crater with a heavy talus of very large limestone fragments. The observed dip of the strata is to the eastward, but in the absence of more complete data around the circumference, no significance as regards crater origin can be attached to this observation. No evidence for a raised rim was seen; a meteorite crater of this size would probably have shown a definite rim in keeping with the nature of the surrounding terrain.

IV. CONCLUSION

In reviewing the evidence presented above, most weight on the five craters near Cabrerolles and Faugeres is naturally attached to that from Le Clot, in view of its large size, the clear delineation of its profile and the numerous rock outcrops occurring within its circumference. Since conditions at Le Clot were on the whole excellent for the detection of the unusual and diagnostic attitudes of sediments commonly associated with a meteorite crater, the fact that such attitudes were not observed seems rather strong evidence against a meteoritic origin for this feature. Less strong but by no means negligible evidence is the absence of a raised rim surrounding the crater. While the irregularity of the surrounding terrain might have partially obscured such a feature, it is very unlikely that it would have been completely concealed. It would appear, therefore, that only if some new and completely unequivocal piece of positive evidence were discovered, would we be justified in continuing to regard Le Clot as a meteorite crater. Similar considerations apply to the other four craters examined. In no case was any positive evidence adduced to connect these features with meteorite impact. It is questionable, therefore, whether it is justifiable to retain even as a working hypothesis, the idea that the group of craters in the Cabrerolles-Faugeres region was formed by a cluster of meteorites and it would be in order to search for other causes.

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