CANADA
DEPARTMENT OF ENERGY, MINES AND RESOURCES
Observatories Branch

PUBLICATIONS
of the
DOMINION OBSERVATORY
OTTAWA

Volume XXXIX • No. 4

ON THE DEPOSITION OF SEDIMENTS IN CRATERS

C. S. Beals and A. Hitchen

THE QUEEN'S PRINTER
OTTAWA, 1970

CONTENTS

ON THE DEPOSITION OF SEDIMENTS IN CRATERS

C.B. BEALS AND A. HITCHEN

ABSTRACT: Scale model experiments in sedimentation have been carried out using a small artificial crater with a depth-to-diameter ratio corresponding to an impact crater a mile in diameter. The experiments were performed under deep water conditions using both mechanical and chemical means of deposition. The results indicated that the crater was obliterated after the deposition of a depth of sediments approximately three times the floor-to-rim depth of the crater. Since an impact crater of one mile diameter is about 800 feet deep, the experiments indicated that a crater of this size would be obliterated by sediments of very moderate depth (2400 feet).

Profile studies of the model crater made during the process of sedimentary deposition, have revealed interesting analogies with the Holleford crater (known to be an ancient meteorite crater filled with Paleozoic sediments) and with the Mecatina crater, the origin and subsequent history of which are still uncertain.

RÉSUMÉ: Les auteurs ont effectué des expériences de sédimentation sur maquette à l'aide d'un petit cratère artificiel ayant un rapport profondeur-diamètre correspondant à celui d'un cratère d'impact d'un mille de diamètre. Ils ont fait les expériences dans des conditions simulant l'eau profonde avec des moyens chimiques et mécaniques de mise en place des sédiments. Le cratère a été oblitéré par le dépôt d'une couche de sédiments d'une épaisseur égale à trois fois environ la profondeur du fond au bord du cratère. Étant donné qu'un cratère d'impact d'un mille de diamètre mesure environ 800 pieds de profondeur, les expériences ont indiqué qu'un cratère de ces dimensions serait oblitéré par des sédiments d'une épaisseur relativement faible (2,400 pieds).

Des études de profils du modèle de cratère effectuées pendant le processus de sédimentation ont révélé des ressemblances intéressantes avec le cratère Holleford (ancien cratère de météorite rempl. de sédiments du Paléozoïque) et avec le cratère Mecatina, dont l'origine et l'histoire demeurent incertaines.

Introduction

Since investigations by V.B. Meen (1950, 1957) indicated that the New Quebec or Chubb Crater in northern Quebec was caused by the impact of a large meteorite, fifteen other circular features in Canada with approximately the same number in other parts of the world, have been assigned a similar origin. Unlike the New Quebec Crater, which is a relatively recent object with important diagnostic aspects of an impact origin still intact, most of the other features are very old, of the order of tens or hundreds of millions of years. Consequently, erosion and deposition have so altered them that more indirect methods have had to be used for their identification. Reviews of recent investigations with suitable references have been presented by Beals, Innes and Rottenberg (1963); Beals and Innes (1964); Beals and Halliday (1967a and b); and by Dence, *et al.* (1968).

In this paper we take for granted the meteorite impact origin of the above-mentioned sixteen Canadian craters, about thirty other craters or clusters of craters on the earth's surface and the majority of lunar craters. Other proponents of the same view are Dietz (1965), Baldwin (1963), Shoemaker (1962), and von Englehardt, *et al.* (1968). A different point of view has been upheld by Currie (1965) and McCall (1965), who consider that most of these craters have a volcanic origin.

Of the sixteen Canadian craters so far identified as impact features with varying degrees of probability, six – Brent (Millman, *et al.*, 1960), Holleford (Beals, 1960), West Hawk Lake (Halliday and Griffin, 1967), East Clearwater Lake (Dence, *et al.*, 1965), Deep Bay (Innes, *et. al.*, 1964), and Skeleton Lake (Dence 1968b) – are partially filled with consolidated sediments ranging in age from 60,000,000 to 600,000,000 years. All of these craters are in Precambrian rock or on the border between Precambrian and Paleozoic areas and no similar features have been identified with any certainty in extensive areas of sediments such as the Canadian Prairies. This suggests that large meteorite impacts may have been considerably more frequent in Precambrian or early Paleozoic than in subsequent time, so that impact scars that were formed in the Precambrian basement or in the deeper sedimentary layers were covered over and obliterated by later sediments. One of the objects of this investigation is to study the process of deposition in craters by model experiments and to try to estimate the depth of sediments required to obliterate a crater of known depth.

A second problem which has arisen in connection with the study of aerial photographs of the Canadian Shield concerns the identification of certain features whose appearance suggests that they may be ancient craters (meteoritic or otherwise) covered over by altered sediments but still retaining indications of their original form (Beals, *et. al.*, 1963, p. 273). The interpretation of most of these features remains highly controversial. They have been included in the present discussion in an attempt to clarify to some extent their relationships with the features mentioned in the preceding paragraphs.

Model Experiments in the Deposition of Sediments in Craters

The principle of the experiments was to set up a model crater in a plain, covered with relatively deep water. Sediments were then deposited first by mechanical and secondly by chemical methods and the gradual disappearance of the crater was observed using precise methods of measuring depth and horizontal location. The miniature crater used in the experiment was a brass casting 29.7 cm in diameter and 2 cm thick

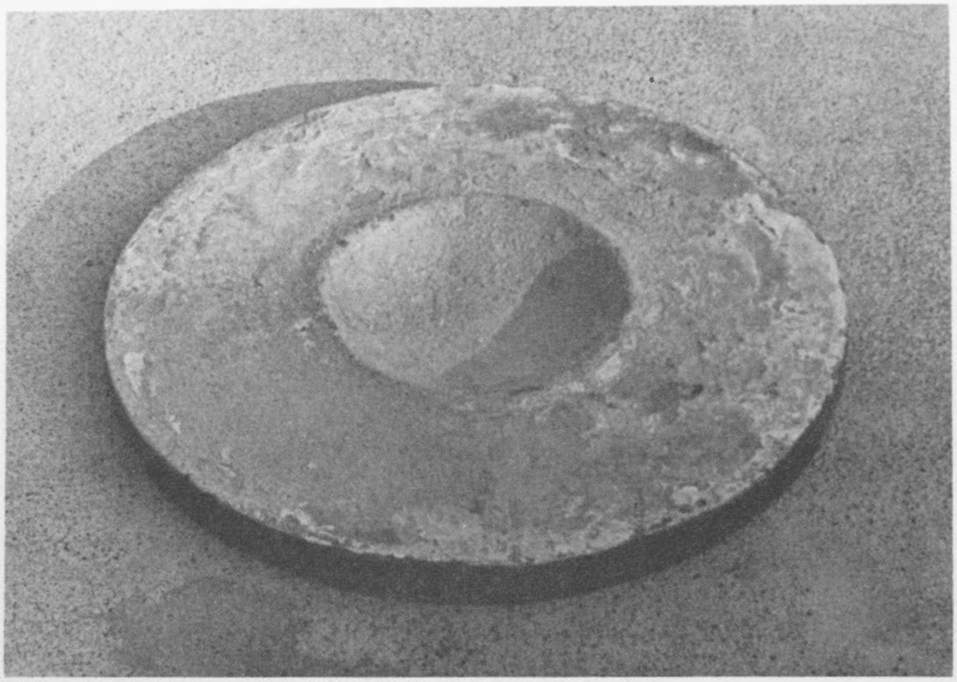
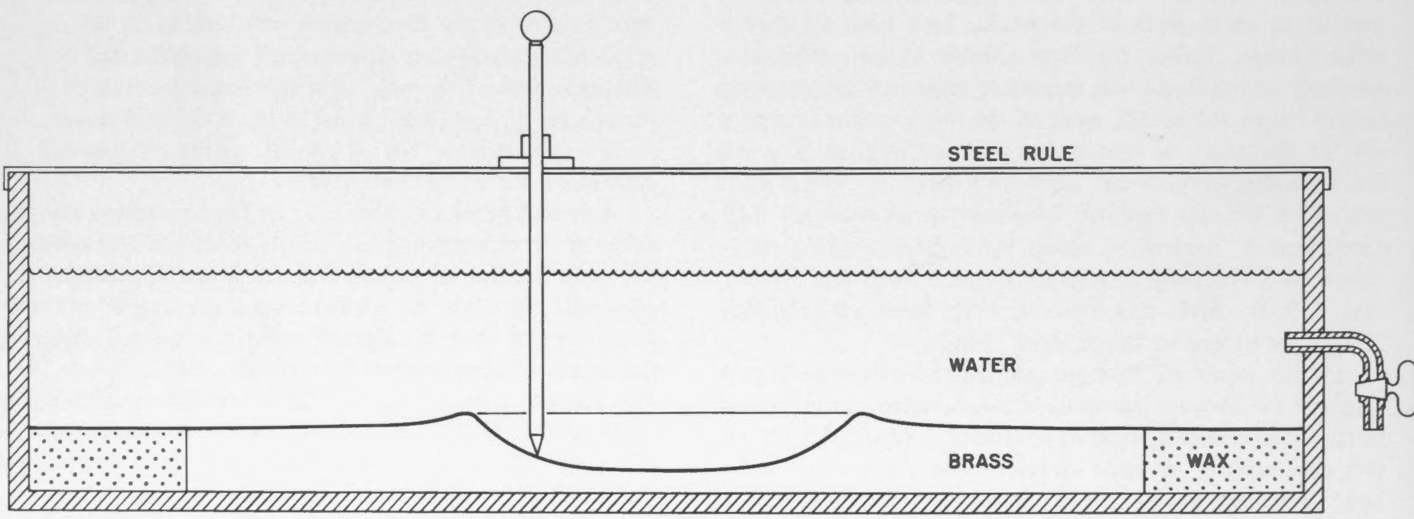


FIGURE 1(a). Model crater in the form of a brass casting. Diameter of crater rim 12.7 cm. Depth of crater (rim to floor) 1.7 cm. Over-all diameter of casting 29.7 cm. The surface of the model has been roughened by the process of chemical deposition (C.S. Beals).

FIGURE 1(b). Section of experimental arrangement showing wooden tank, crater model, measuring pointer and other details mentioned in text.



on the outer edge. The upper surface was moulded to the approximate form of a standard meteorite crater of the same proportions as a natural crater a mile in diameter. No mathematical formula was used but an interpolation between the Barringer crater 4,150 feet in diameter and the New Quebec Crater 12,000 feet in diameter was made. (See diagrams comparing these two objects by Meen (1950) and Millman, *et al.* (1960).) The diameter of the rim of the model crater was 12.7 cm while the depth from the top of the rim to the bottom of the crater was 1.7 cm. The inner slopes of the crater were steep (around 35°) while the outer slopes were gradual, reaching the level of the hypothetical surrounding plane at about 15 cm from the centre. A photograph of the model is shown in Figure 1(a).

The brass casting was placed in the centre of a wooden tank 43 cm square and 10 cm deep. Melted paraffin wax was poured into the tank up to the level of the rim of the brass casting corresponding to the surrounding plain of a natural crater and the tank was filled with water or chemical solution. A glass tube and stopcock made it possible to fill the tank or draw off the water without serious disturbance of the sedimentary deposits (Figure 1(b)).

The Mechanical Deposition of Sediments

Mechanical deposition was tried first. After some preliminary experiments 600-mesh carborundum was selected as the material to be deposited.

The experimental procedure was as follows. The tank was filled with water to a depth of 6 cm and the surface was divided into nine equal areas by strings stretched across the top of the tank. Twenty grams of carborundum suspended in a beaker containing 80 cc of water was gently poured into each of the nine areas in turn. The spout of the beaker was moved systematically across each area as the pouring took place, to ensure as much uniformity as possible. Actually at each location, the liquid with suspended sediments spread over the whole surface of the tank but the deposition was probably localized to a certain extent, making the division into separate areas desirable.

The pouring gave rise to numerous interesting turbulence patterns which could be clearly seen when the first beaker of sediment was introduced into the clear water of the tank. Some of them appeared to be almost identical with the patterns of spiral nebulae known from familiar photographs, e.g., the very beautiful spiral in *Canes Venatici.*

The deposition continued till the tank was full, care being taken to see that each of the nine areas received the same amount of sediment. Once the tank was full it was left undisturbed for at least 24 hours to allow the sediments to settle and consolidate. About half the water was then drawn off and the process of deposition was repeated. The complete experiment took several weeks and was continued until the form of the crater was no longer discernible.

Measurement of Successive Stages of Deposition. After each stage of deposition, when suspended sediment had been introduced into all nine areas and a period of 24 hours for settling had been allowed, the resulting crater profile was measured along an east-west and a north-south line each passing through the centre. A horizontal steel millimetre scale was clamped to the wooden tank with the graduated edge passing through the centre. A sliding device was fitted to the steel scale and this device carried a steel pointer also graduated in millimetres and able to move freely in a vertical direction (Figure 1(b)). The measurements were carried out without removing the water from tank. The lighting was arranged so that contact with the crater surface occurred when the sharpened lower end of the pointer coincided with its shadow. Readings were estimated to 0.1 mm and the results are illustrated in Figure 2.

An examination of the graph shows that the original crater form (lower profile) was gradually obscured with increasing depth of sediments until it effectively disappeared when the depth of sediments over the crater floor was approximately three times the depth of the crater from rim to floor. After the measurements had been completed a section of the sedimentary layer was removed and is shown in Figure 3. In this figure one half of the brass casting forming the model crater is shown in the foreground while the surface of the dried and hardened sedimentary material occupies the background. The section follows closely the results indicated in the graph of Figure 2. Clearly seen are the divisions between five successive stages of deposition corresponding to the measured surfaces, while between, less clearly visible, are the nine 'varves' resulting from nine successive pourings of suspended sedimentary material into the water covering the crater.

The Chemical Deposition of Sediments

For the chemical deposition experiments, preliminary trials were carried out to find suitable reagents that, when combined, would give a crystalline, nongelatinous type of precipitate that settled rapidly. A combination of calcium chloride and oxalic acid was found to meet the requirements and these materials were finally adopted.

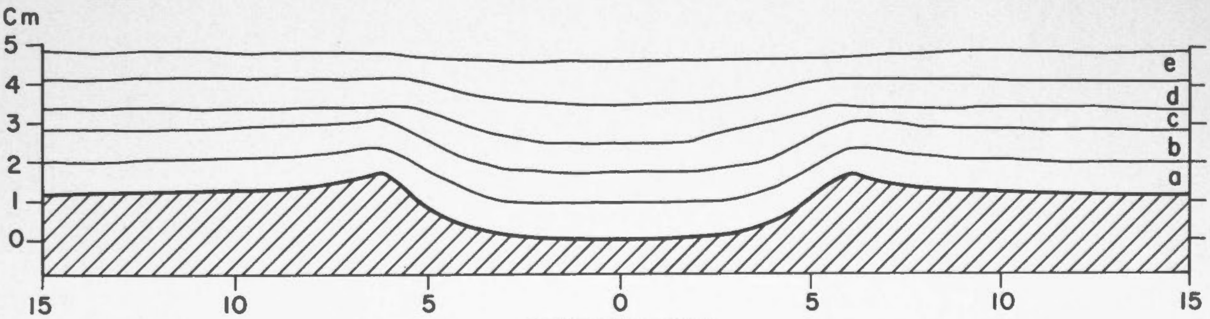


FIGURE 2. Profile of model crater; sedimentary layers lettered from *a* to *e* (Mechanical depositions).

The same tank and model crater that was used for the mechanical deposition experiments was used for the chemical deposition of sediments.

The experimental procedure was as follows. The tank was filled with a solution of calcium chloride to a depth of about 6 cm. An equivalent solution of oxalic acid was then introduced into the tank with the aid of a mechanical device designed to produce uniform distribution. To do this, a 3/8-inch copper tube 41 cm long was closed at both ends with a supply tube soldered to it at right angles to the centre. The 41-cm tube was

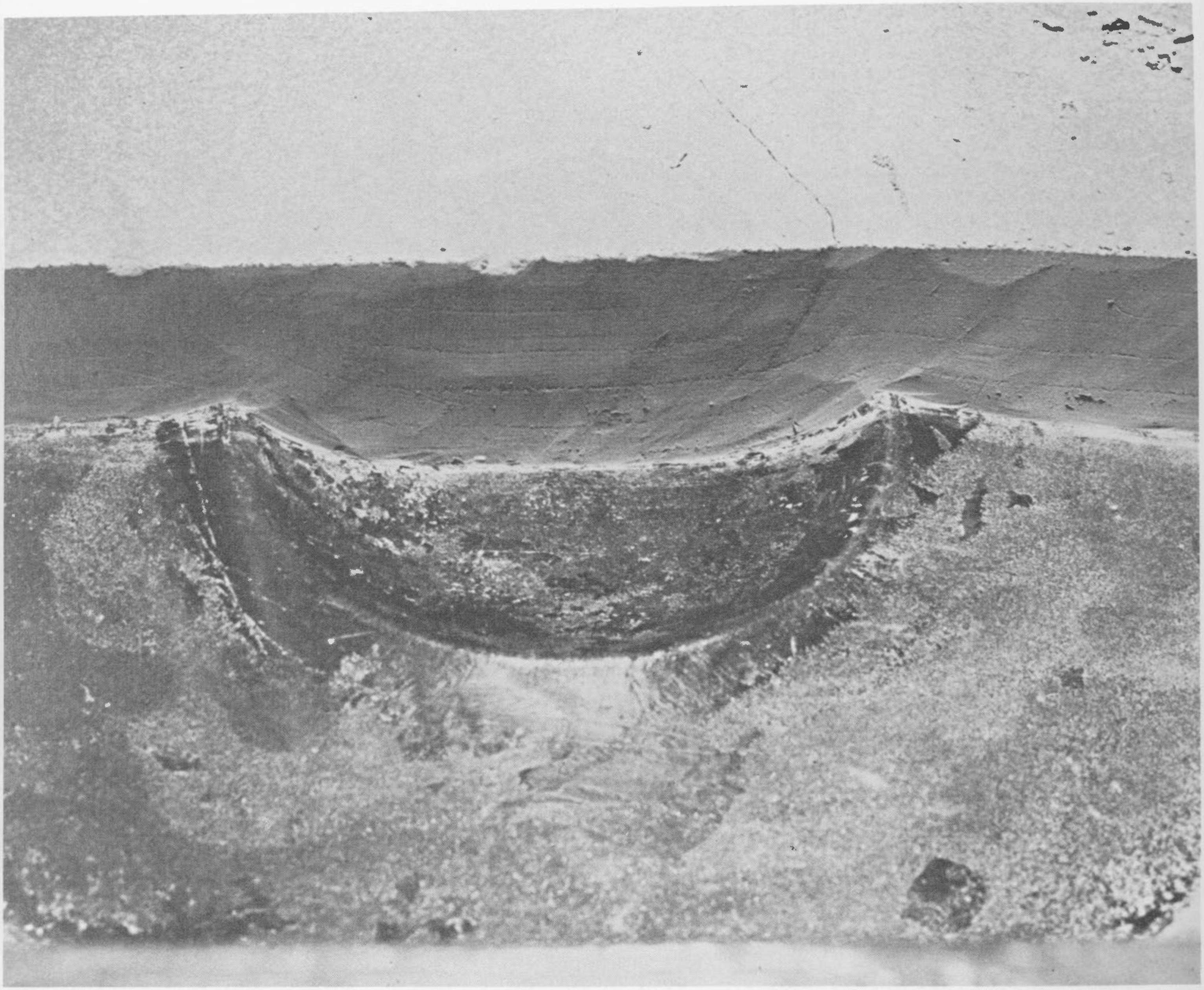


FIGURE 3. Section of sedimentary covering of model crater. In the foreground appears one half of the brass crater model from which the sedimentary covering has been removed. In the background the five main layers of sediment are clearly seen with faint indications of nine 'varves' in each layer.

provided with ten small holes uniformly spaced throughout its length while a reservoir of oxalic acid solution was connected to it by rubber tubing. The flow of oxalic acid solution through the tubing was regulated by a screw clamp. The copper tube was then immersed in the tank solution and moved slowly and uniformly from end to end by a motor operated device, mounted on rails and provided with limit switches to reverse direction as the end of the tank was approached.

The white, crystalline precipitate of calcium oxalate came down uniformly over the crater as the tube was moved from end to end and this procedure was continued until the calcium chloride solution was exhausted. The precipitate, however, was flocky and lacked density so that it soon became apparent that gravity alone would not be sufficient to provide the necessary degree of consolidation. The procedure was then adopted of carefully drawing off the supernatant solution without disturbing the sediment. The moist sediment was then permitted to dry and harden by exposure to air over several days.

Measurements of the depth of the sediment were made and the tank was again half filled with a calcium chloride solution, once more care being taken to disturb the sediment as little as possible. A solution of oxalic acid was added to produce additional sediment which was allowed to settle and consolidate. The supernatant liquid was drawn off as before and the moist sediment permitted to dry again.

The deposition of calcium oxalate was continued in this manner over a period of several weeks until the form of the crater was no longer discernible.

The drying procedure for consolidating the sediments was accompanied by certain difficulties which included cracking of the surface and the production of numerous irregularities such as are seen in the mud of river banks when flood waters have receded. These showed up conspicuously in the measurements. In Figure 4 a section of the chemically deposited sediments is shown. It is clear that the layering is by no means as even and regular as was the case for the mechanically deposited sediments. In spite of these departures from regularity, however, the result is much the same and the chemical experiments confirmed the earlier result that the crater was effectively obliterated by a depth of sediment approximately three times the rim-to-floor depth of the crater.

Discussion of Results

While an experiment of this kind far from duplicates natural conditions, there are nevertheless reasons for believing that the general results should lead to valid conclusions. In a natural sea there are of course such things as tides, currents, storms, irregularity of bottom terrain, and changing rates of deposition, which could interfere with the kind of regular and even deposition of sediments associated with experimental sedimentation. At the same time there exist large areas of natural sediments that suggest considerable uniformity of conditions over long periods of time. Even if rates of sedimentation changed, the effects of gradually increasing thickness should eventually produce a similar result. The limitation of the experimental area by the walls of the tank certainly introduces a situation not found in nature since the sedimentary material poured in is limited in the extent to which it can spread out. It is considered however that this effect would be balanced in the natural case by material that could enter the chosen area from outside. Providing the introduction of sediments is gentle and even over the small area available, it would seem reasonable to suppose that the results should be similar to those of even deposition over a very much larger area. The absence of any clearly marked effects in the vicinity of the walls of the tank suggests that this is indeed the case.

As has already been mentioned, an examination of the profiles of Figures 2 and 4 indicate that obliteration occurred when the depth of sediments over the crater floor was approximately three times the rim-to-floor depth of the crater. Since this depth for a mile-wide impact crater is approximately 800 feet (Baldwin, 1949) a fairly moderate depth of sedimentary rock, less than 2500 feet, would be adequate to obscure an uneroded crater of this size. Actually this would represent an ideal case unlikely to occur under natural conditions since a natural crater with a sharply elevated rim could scarcely remain uneroded for any appreciable length of time. In a period short relative to the time required for the deposition of 2500 feet of sediments, the rim would probably have largely disappeared. Indeed if the crater were formed on land appreciably above sea level, most of the rim would probably have disappeared before the sea rose and sedimentary deposition began. In addition, erosion of the rim would tend to fill up the depression below plain level so that the obscuring effect of sedimentary deposition would be considerably more efficient than the graphs of Figures 2 and 4 would suggest.

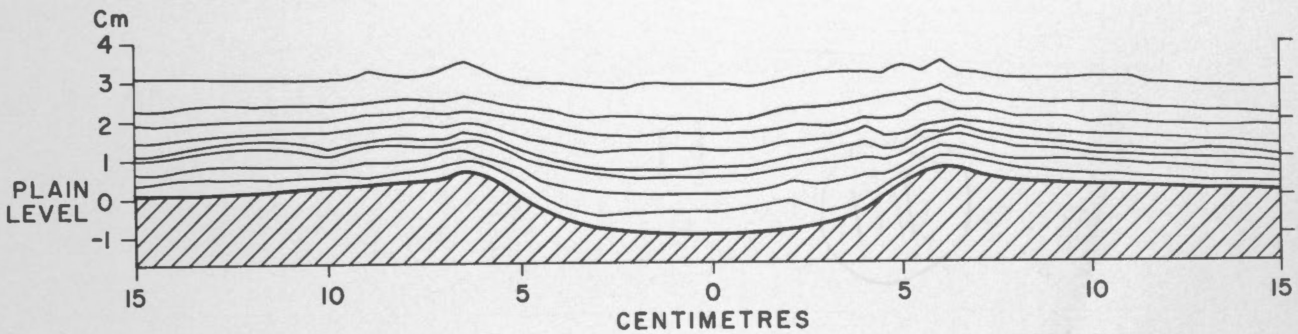


FIGURE 4. Profile of model crater, showing sedimentary layers (chemical depositions). The process of consolidation by drying each layer before the deposition of the next caused cracks and other irregularities, making the result less smooth than for mechanical deposition.

Of interest in connection with the obliteration of ancient craters is a recent suggestion by Dence (1968a) that the original height of the rims of large terrestrial craters could be considerably smaller than had formerly been supposed, due to slumping of the rims during the process of crater formation. Such a suggestion is given credence by the much greater value of gravity on earth (six times that on the moon).

The Holleford Crater

An example of the partial obliteration of a crater by sediments in nature may be found in the Holleford Crater of southern Ontario (7700 feet in diameter) which is partially filled in and covered over by Paleozoic sediments. (Available evidence suggests that this crater was once completely covered by sediments which were later partially removed by erosion, glacial or otherwise.) The estimated height of the rim above

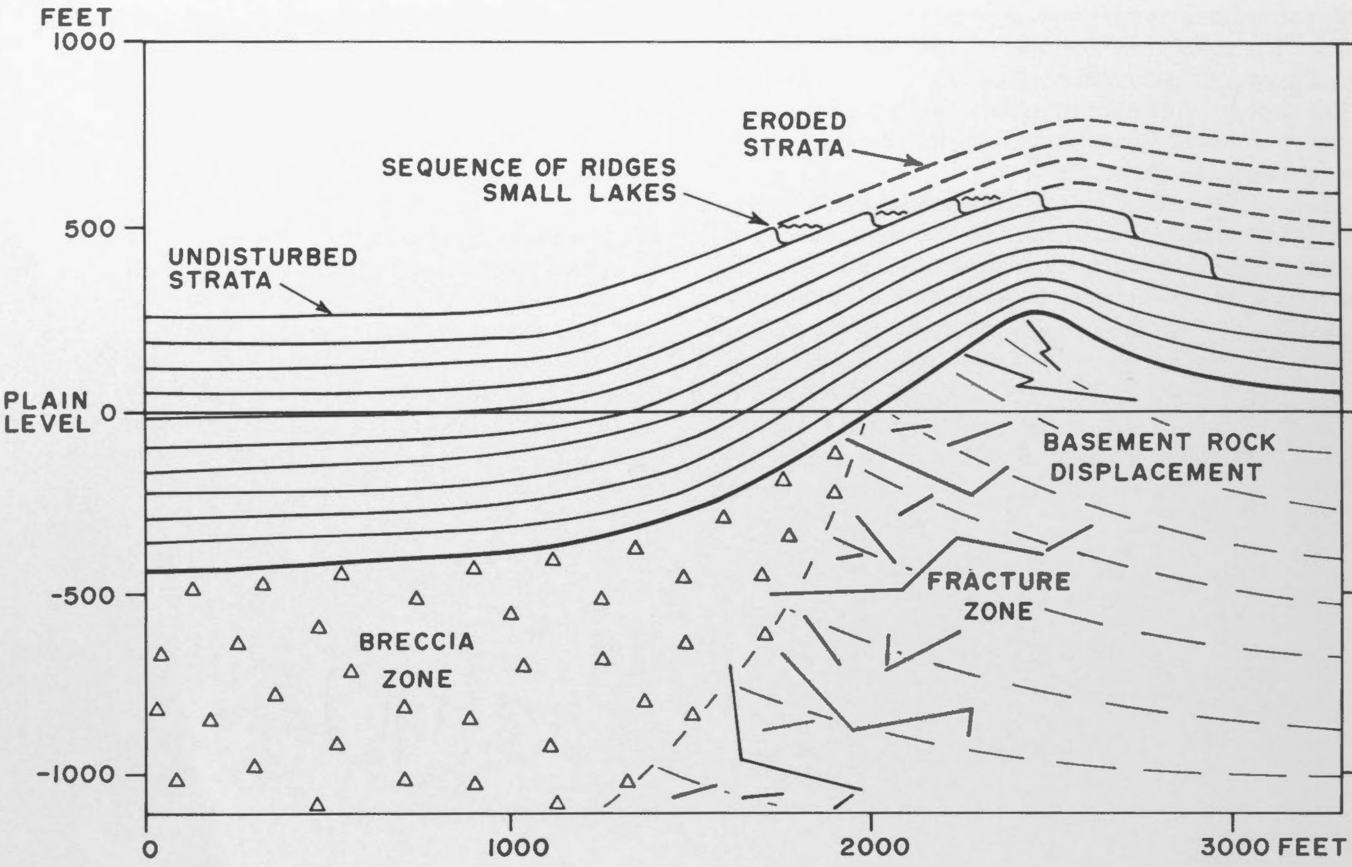


FIGURE 5. Diagram of a crater filled and covered over by sediments that have been subsequently eroded. Note erosion ridges behind which small lakes are sometimes impounded. The brecciated basement rock, the fracture zone and the displacement of unbrecciated basement rock layers due to impact are shown in the lower part of the figure. For a crater formed in sedimentary rock the attitudes of the basement sediments are quite different from those filling the crater.

plain level for an uneroded crater of this size is approximately 500 feet, while the depth below plain level is 700 feet. Since part of the plain around this crater is now exposed it may be estimated that the part of the original rim still obscured by sediments is around 50 feet above plain level; in other words, it had been mostly removed by erosion before deposition of sediments began. The amount of filling in of the crater before the deposition of marine sediments began is harder to estimate but is believed to be appreciable.

The experiment discussed above was carried out under deep-water conditions corresponding to a relatively rapid rise of a natural sea. It is quite possible that much of such deposition could have occurred in shallow water where the conditions would be quite different. St. John (1968) in a recent study of the Holleford Crater presents evidence indicating that during part of its depositional history it was a freshwater lake and that it was largely filled up by lacustrine deposits before the kind of deep-water deposition discussed in the present paper began. His conclusions, based on geological studies of the drilling cores, suggest that the role of deep-water deposition was considerably less important than Figures 2 and 4 of this paper would indicate. However the general thesis of the efficiency of depositional processes in obliterating ancient craters is reinforced rather than negated by his results. If the processes discussed in his paper could be applied to other buried craters, the depth of marine sediments required to obliterate a given crater apparently is considerably smaller than has been estimated from the present experiments.

Larger craters of about ten or more miles in diameter would be more difficult to obliterate but when all the available evidence (including the suggestions by Dence, already mentioned), is considered, it seems likely that most of them also would disappear in an area like the Prairies where sedimentary rock 500 to 8000 feet thick is the rule (Hume, 1947). Most of the larger craters, such as the two Clearwater lakes, Lac Couture, Carswell Lake, Deep Bay and the newly discovered crater at Baie-St.-Paul (Rondot, 1968; Robertson, 1968) show few above-ground features, suggesting that the original precipitous rims, several thousand feet high consisting to a certain extent of shattered and weakened rock, were eroded in a relatively short time. In addition, the larger features tend to be associated with central uplifts, also of shattered rock which would also be quickly eroded, filling up the crater in the process. For very large craters it has recently been suggested (Baldwin, 1968) that isostatic forces tend to elevate the floors, again aiding in the process of obliteration.

The deposition experiments have indicated that the depth of sediments required to obliterate a crater of moderate size is

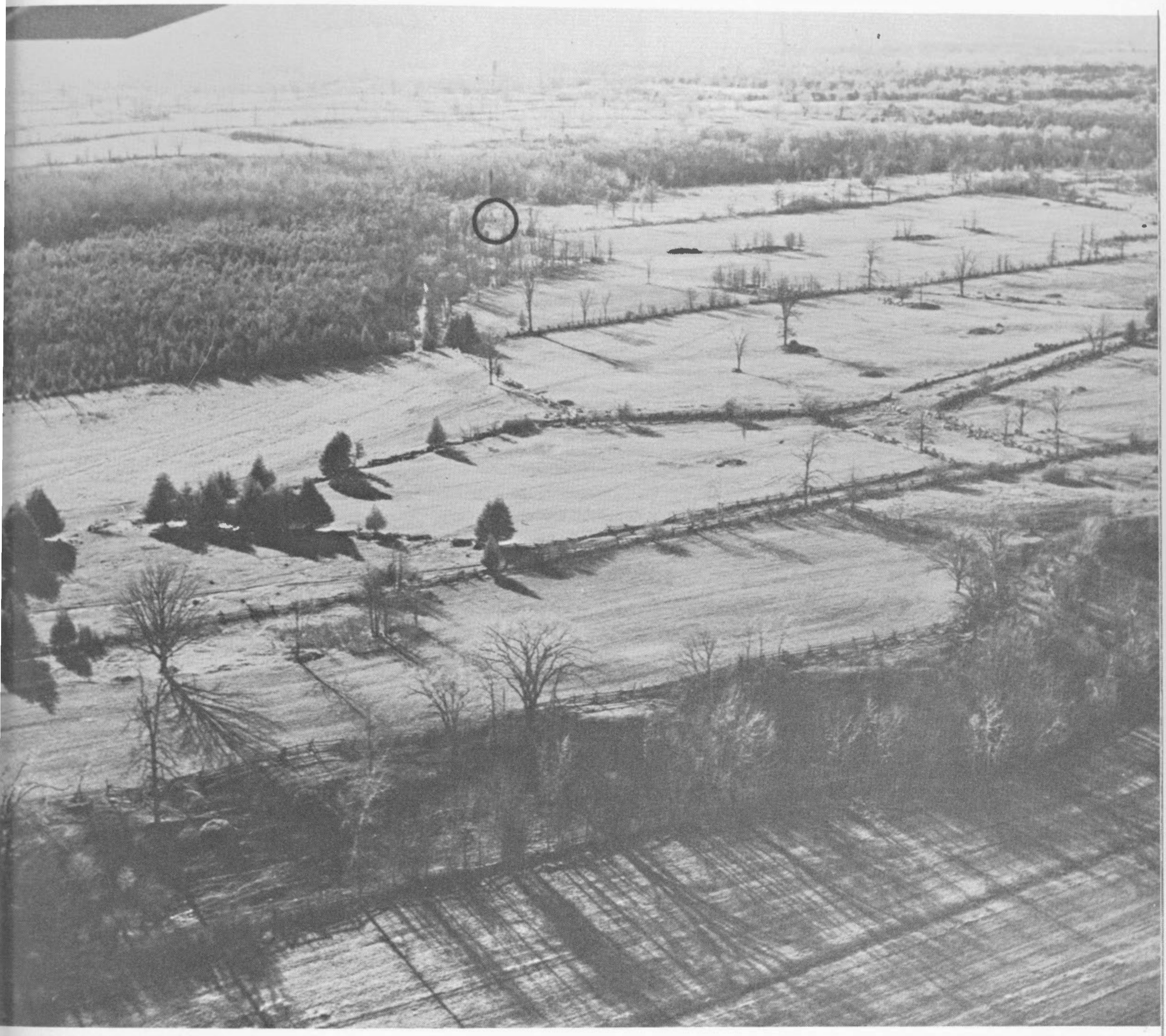


FIGURE 6. In this photograph of an erosion ridge, the steepness of the outward-facing scarp in the immediate foreground is emphasized by the shadows cast by the low sun. This is in sharp contrast with the gentle slope of the fields beyond the scarp toward the centre of the crater which is marked by a black circle (aerial photo by Lightfoot Studio, Kingston, Ont.).

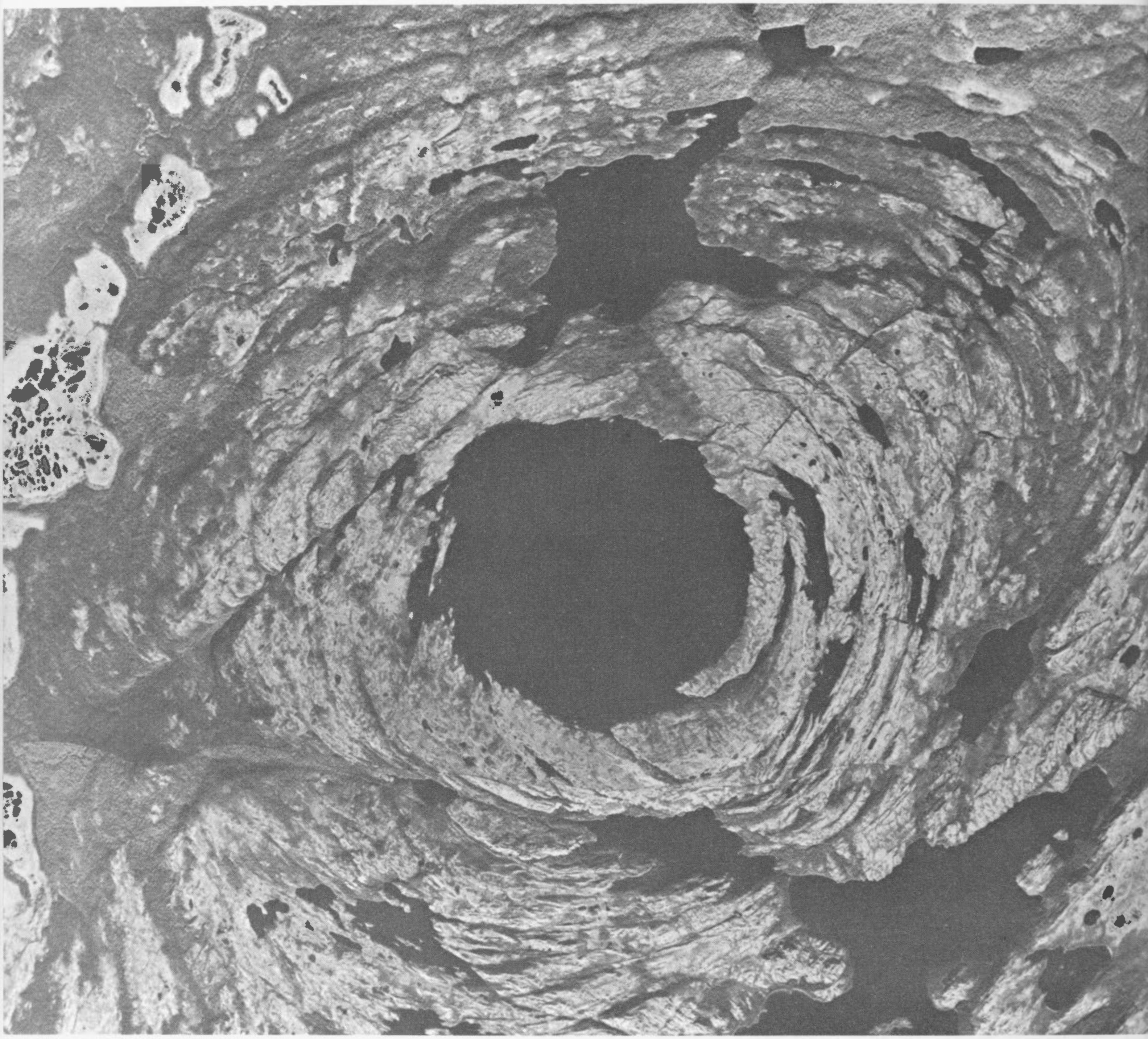


FIGURE 7. Aerial mosaic of Mecatina crater, Quebec. The central lake has a diameter of 4000 feet while the whole circular stratified area is about three miles in diameter (National Air Photo Library).

relatively small. If we are correct in assuming that meteorite impacts were considerably more frequent in Precambrian time, we may reasonably expect that practically all of the smaller and more numerous craters of one to two miles or less in diameter would have disappeared long before the sediments of the Prairie region of Canada reached their maximum thickness. For larger craters in the 10- to 20-mile diameter range, such evidence as we have strongly suggests that they also would have been obliterated by the combined action of erosion and deposition over the immense periods of time that have elapsed since their formation. Thus it is not surprising to learn that most if not all of the ancient impact scars known in Canada are found in the Canadian Shield. It seems entirely probable that the Prairie areas were originally subjected to the same intensities of meteorite bombardment as the rest of Canada and that the remains of impact scars are still present under the sedimentary rocks which cover these areas. Undoubtedly as time goes on, geological and geophysical investigations aimed at determining the nature of subsurface structures in the Prairie regions will continue and become more efficient. No doubt also drilling operations aimed at penetrating to the Precambrian basement will be a feature of such investigations. It seems probable, therefore, that sooner or later evidence will be found of structures formed by meteorite impact in this extensive and interesting region making up approximately one fifth of the land area of Canada.*

Enigmatic Circular Features Suggestive of Buried Craters

Circular features observed on aerial photographs of the Canadian Shield appear to be characterized by surfaces of rock strata whose attitudes bear no relation to the well known sharply upturned strata of meteorite craters formed in stratified rock as described by Baldwin (1963), and Shoemaker (1960). Some of these features, ranging from two miles to seven miles in diameter have been described by Beals, *et al.* (1963, p. 273). Probably the most interesting aspect which has so far come to light, is certain points of resemblance to the Holleford crater which has been shown to be an ancient meteorite crater filled in an almost entirely covered over by Paleozoic sediments. Since this is also the situation dealt with in the sedimentation experiments described in the first part of this paper, we will use profile *b* of Figure 2 to illustrate some points in the discussion. This particular profile corresponds to a crater buried under approximately 1000 feet of sediments. Although this is considerably greater than the depth of the sediments covering Holleford, the similarity is sufficient to serve as a basis for discussion. To make possible presentation on an adequate scale we will use only part of the profile, from the centre to a point nearly reaching plain level outside the crater (Figure 5).

It has already been pointed out in the first part of the paper that Holleford was covered by sediments which were subsequently eroded by glacial action or other forms of erosion. A very distinctive feature of the eroded strata is a succession of ridges with steep scarps on their outward-facing sides with gradual slopes on the side toward the crater centre. These ridges have been described elsewhere by Beals (1960). In locations shown on an aerial photograph of the crater, it may be seen that there are as many as six successive major steps of this kind between the rim and the centre of the crater. Stereoscopic views of these striking features at Holleford are provided by a stereoscopic pair of photographs accompanying the same publication. One of these ridges is seen in the immediate foreground of Figure 6 on a photograph taken from an aircraft flying low over the Holleford Crater. A similar set of eroded ridges is shown in the drawing of Figure 5, which illustrates the situation both at Holleford and at other more controversial craters subsequently discussed.

The Mecatina Crater

This feature is illustrated in Figure 7, a mosaic very kindly provided by the map service of the Department of Energy, Mines and Resources. Here the succession of exposed strata with their steep outward-facing scarps and gentle slopes toward the centre are even more conspicuous than at Holleford. The mosaic shows that exposed scarps and the depressions behind them are so deep that they have impounded about a dozen small elongated ponds or lakes.

In discussing the phenomena associated with this crater the term 'strata' is used to describe clearly distinguishable layers of rock lying one upon the other after the manner of sedimentary deposits whose characteristics are very well known. A closer look at a good example of these particular strata is available in Figure 8, photographed with a hand camera at Mecatina from a low-flying aircraft. This picture shows five successive exposed layers of rock clearly lying one upon the other and the term strata certainly seems appropriate to describe them.

STRATIFIED CIRCULAR STRUCTURES

Name and location	Long. (W) ° ′	Lat. (N) ° ′	Diameter (miles)
Mecatina, Quebec	59 22	50 50	2.0
Lake Michikamau, Labrador	64 27	54 34	3.5
Menihek Lake (1), Labrador	66 40	53 42	3.0
Menihek Lake (2), Labrador	67 10	54 19	2.5
Labrador	68 31	65 55	1.5
Labrador	68 43	65 58	2.0
Labrador	69 05	67 13	2.0
Labrador	69 28	66 51	2.7
Sault-au-Cochons, Quebec	70 05	49 17	7.0
Parry Sound, Ontario	79 56	45 22	1.4

Note: Although there appears to be a family resemblance between the features of this list, until they are investigated in detail it is by no means certain that they are all due to the same cause.

*Since the above paragraph was written Carrigy (1968) has published studies of rock cores at Steen River, Alberta which suggest the possibility of an impact event which occurred in the Precambrian basement, and later Paleozoic sediments before it was covered by 600 feet of Quaternary and Cretaceous deposits. Several other similar observations at other sites are now under consideration (Dence, 1968b).

FIGURE 8. Four successive ridges of eroded strata, Mecatina crater. The dip of the strata is much steeper than the photograph suggests (low-level aerial photo by C.S. Beals).

Actually the stratified rock at Mecatina when examined on the ground, was found to be granite or granite gneiss and in some locations as many as ten successive layers were observed, overlapping each other. The thickness of the strata varied from about a foot to 10 feet or more. In one instance where a cliff, due to a fault, exposed a considerable height of distinguishable strata, some of the relatively thick layers were separated by thin layers of a black material which, upon examination, was found to be quartz upon which flat lichens of a blackish color had grown. These identifications were made by Dr. K.R. Dawson of the Geological Survey of Canada who accompanied one of the authors on a visit to the Mecatina crater in 1960.

In addition to Mecatina, nine other somewhat similar features have been found and their locations and diameters are listed in the accompanying Table*. The discussion which follows is limited largely to the Mecatina feature which has been observed in much more detail than any of the others.

Discussion

As already noted, the form of the Mecatina crater and its similarities with Holleford suggest the possibility of a circular depression filled in and covered over by later sediments. Of course the granite or granite geniss which comprise the strata of this feature could hardly be called sediments in the ordinary meaning of that term. Nevertheless they might have been sediments at one time which have been altered by heat, pressure, or other geological processes since they were laid down. There appears to be general agreement that certain types of gneiss, for example paragneiss, were once sedimentary rocks which were brought to their present state by processes of metamorphism (heat, pressure and other conditions resulting from deep burial). As for granite, there does exist what is known as the granite controversy (Read, 1956) in which a sedimentary origin is postulated for at least some of the well known granite areas of the world. The granite controversy has never been entirely resolved and any review of the complex arguments surrounding it is beyond the scope of the present paper. However it does seem worth while to mention that very large areas in the vicinity of the Mecatina crater, when observed from the air directly, or studied on aerial photographs, are very disturbed in appearance and suggest the deposition of ancient sediments on a basement of distinctly irregular relief. For the purposes of the present discussion it will be assumed that this is a correct interpretation. We hope

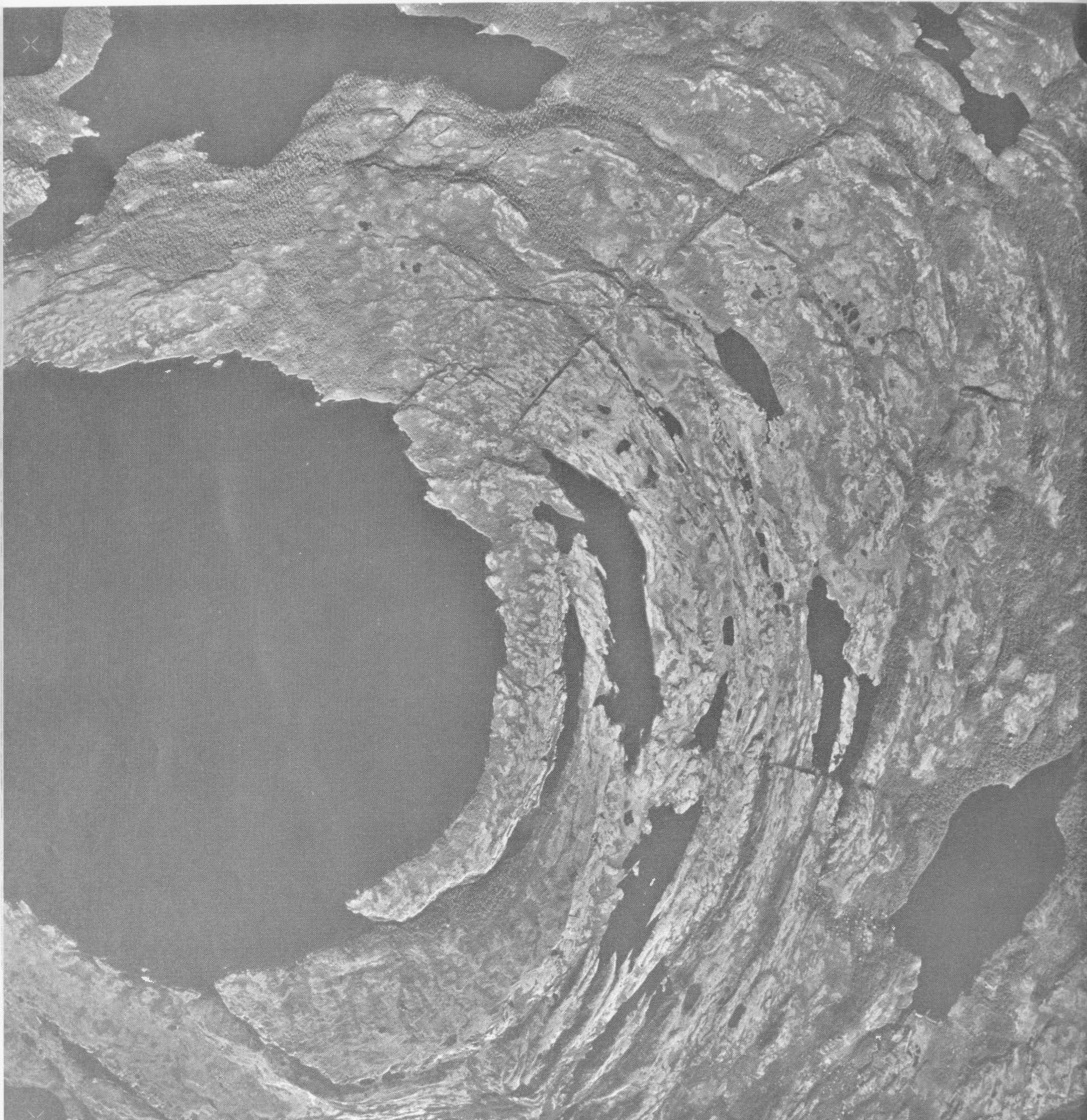
FIGURE 9 (pages 115, 116 and 117). Stereoscopic vertical photographs of the Mecatina crater and of part of the eastern half, illustrating the circular character of the strata and the numerous impounded lakes and ponds. The stereoscopic view considerably exaggerates the dip of the strata (National Air Photo Library, A17548 - 23, 24 and 25).

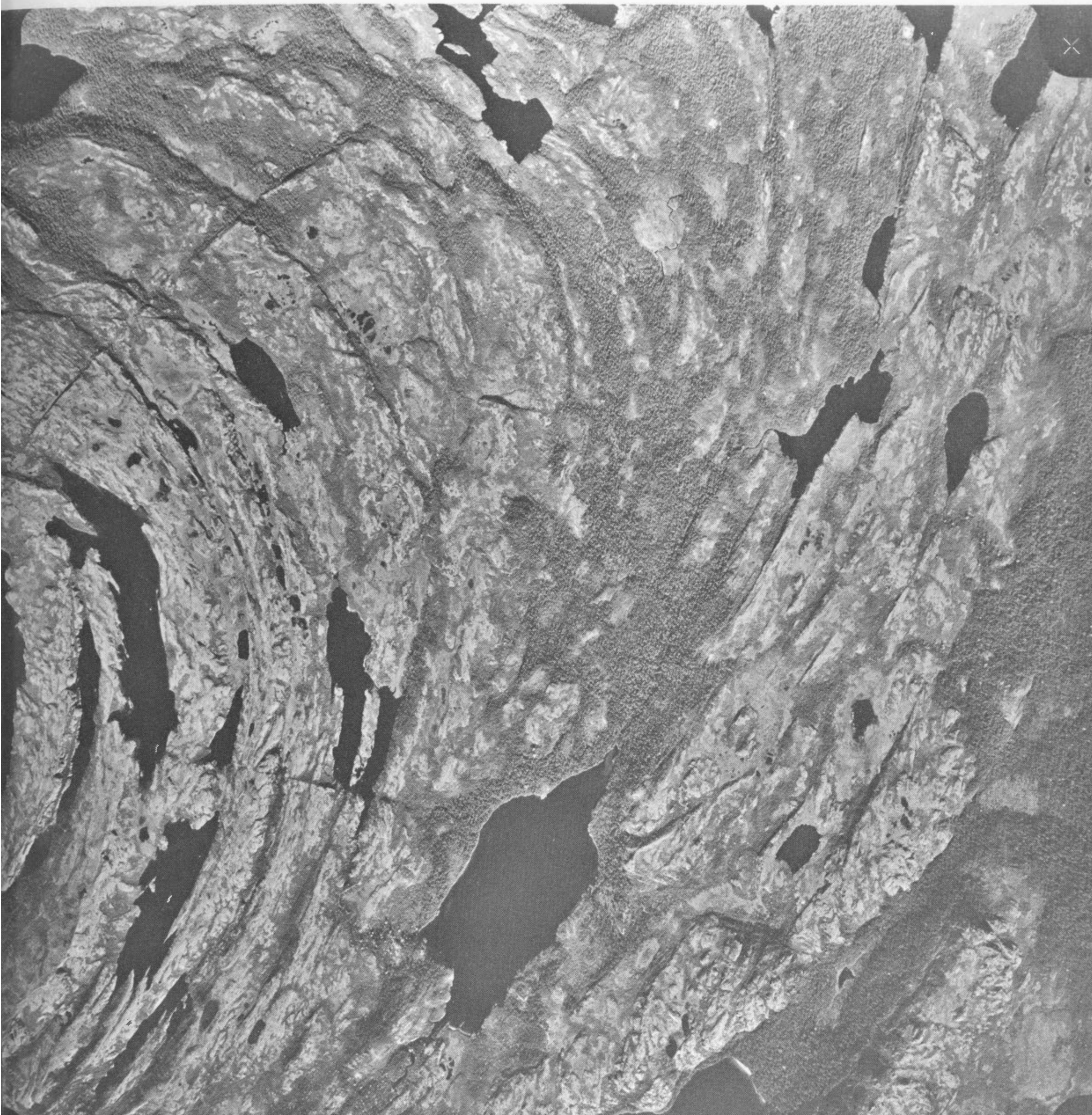
*There are some reasons for including the great arc of eastern Hudson Bay in this list (Beals, 1968).

INSERT for

Volume XXXIX No. 4, Publications of the Dominion Observatory: *On the Deposition of Sediments in Craters,* by C.S. Beals and A. Hitchen.

This page is reprinted separately to facilitate stereoscopic coverage of photographs on pages 116 and 117.


A17548-24


A17548-25

that subsequent investigations of the interesting features of the table may help to decide for or against its validity.

Granted that the rock strata covering the Mecatina crater are altered sediments, what conclusions can be drawn about the surface on which they were deposited? At present there is only the probability of a circular depression in the Precambrian rock at that location. There appears to be no clear evidence of a rim such as would be present in an uneroded impact crater, since there is no reversal of the direction of dip of the sediments as we go outward from the centre. Even if there were a rim it is doubtful whether without the aid of drilling it would be possible to distinguish between the surface indication of a meteoritic crater and one due to other causes, for example, certain types of volcanic craters, in particular Maar type craters which are superficially similar to impact craters.* It follows that only studies of the subsurface structure, preferably by drilling and the study of rock cores obtained from depths greater than the thickness of the stratified material, are likely to be of much help in solving the problem. While there would very probably be difficulties in interpretation because of alteration in the material at depth, the effort should be well worth while since it would offer not only the possibility of contributing to the general problem of the identification of ancient craters but also to our understanding of the nature of granite and gneiss.

Acknowledgment

The assistance of Dr. K.R. Dawson of the Geological Survey of Canada in identifying rocks at Mecatina and in reading the manuscript of this paper is gratefully acknowledged.

References

Baldwin, R.B., 1949. *The Face of the Moon.* Univ. of Chicago Press, Chicago, p. 132.

Baldwin, R.B., 1963. *The Measure of the Moon.* Univ. of Chicago Press, Chicago, p. 10.

Baldwin, R.B., 1968. Rille pattern in the lunar crater Humboldt. *J. Geoph. Res.*, Vol. 73, p. 3227.

Beals, C.S., 1960. A probable meteorite crater of Precambrian age at Holleford, Ontario. *Pub. Dom. Obs.*, Vol. XXIV, No. 6, p. 117.

Beals, C.S., 1968. On the possibility of a catastrophic origin for the great arc of eastern Hudson Bay. *Science, History and Hudson Bay.* C.S. Beals and D.A. Shenstone (Ed.), Dept. Energy, Mines and Resources, Ottawa, p. 985.

Beals, C.S., and I. Halliday, 1967a. Impact craters of the Earth and Moon. *J. RASC,* Vol. 61, p. 295.

Beals, C.S., and I. Halliday, 1967b. Terrestrial meteorite craters and their lunar counterparts. *Int. Dict. of Geoph.*, Vol. 2. S.K. Runcorn (Ed.), Pergamon Press, London, p. 1520.

Beals, C.S., and M.J.S. Innes, 1964. The identification of ancient meteorite craters. *Meteoritika,* Vol. XXV, p. 3.

Beals, C.S., M.J.S. Innes, and J.A. Rottenberg, 1963. Fossil meteorite craters. *The Moon, Meteorites and Comets, The Solar System,* Vol. IV, B.M. Middlehurst and G.P. Kuiper (Ed.), Univ. of Chicago Press, Chicago, p. 235.

Carrigy, M.A., 1968. Evidence of shock metamorphism in rocks from the Steen River structure, Alberta. *Shock Metamorphism of Natural Materials,* B.M. French and N.M. Short (Ed.), Mono Book Corp., Baltimore, p. 367.

Currie, K.L., 1965. Analogues of lunar craters on the Canadian Shield. *Ann. N.Y. Acad. Sci.*, Vol. 123, p. 915.

Dence, M.R., 1964. A comparative structural and petrographic study of probable Canadian meteorite craters. *Meteoritics,* Vol. 2, p. 249.

Dence, M.R., 1965. The extraterrestrial origin of Canadian craters. *Ann. N.Y. Acad. Sci.*, Vol. 123, p. 941.

Dence, M.R., 1968a. Shock zoning at Canadian craters: petrography and structural implications. *Shock Metamorphism of Natural Materials,* B.M. French and N.M. Short (Ed.), Mono Book Corp., Baltimore, p. 169.

Dence, M.R., 1968b. Skeleton Lake, Ontario. Personal communication.

Dence, M.R., M.J.S. Innes, and C.S. Beals, 1965. On the probable meteorite origin of the Clearwater Lakes, Quebec. *J. RASC,* Vol. 59, p. 13.

Dence, M.R., M.J.S. Innes, and P.B. Robertson, 1968. Recent geological and geophysical studies of Canadian craters. *Shock Metamorphism of Natural Materials,* B.M. French and N.M. Short (Ed.), Mono Book Corp., Baltimore, p. 339.

Dietz, R.S., 1965. Astroblemes, lunar craters, and maria. *Ann. N.Y. Acad. Sci.*, Vol. 123, p. 895.

Englehardt, W. von, F. Hörz, D. Stöffler, and W. Bertsch, 1968. Observations on quartz deformation in the breccias of West Clearwater Lake, Canada, and the Ries Basin, Germany. *Shock Metamorphism of Natural Materials,* B.M. French and N.M. Short (Ed.), Mono Book Corp., Baltimore, p. 475.

Gold, D.P., and B. Voight, 1967. Report on the Mecatina structure. Pennsylvania State Univ. Fourth Annual Report (Jan. 1966-Dec. 1966) to NASA, Washington, D.C., Grant No. NSG-473, p. 6.

Halliday, I., and A.A. Griffin, 1963. Evidence in support of a meteoritic origin for West Hawk Lake, Manitoba, Canada. *J. Geoph. Res.*, Vol. 68, p. 5297.

Halliday, I., and A.A. Griffin, 1967. Summary of drilling at the West Hawk Lake crater. *J. RASC,* Vol. 61, p. 1.

Hume, G.S., 1947. *In* Officers of the Geological Survey of Canada. Geology and economic minerals of Canada. *Geol. Surv. Canada,* Econ. Geol. Series, No. 1 (Third Edition), p. 196.

Innes, M.J.S., W.J. Pearson, and J.W. Geuer, 1964. The Deep Bay crater. *Pub. Dom. Obs.*, Vol. XXXI, No. 2, p. 21.

McCall, G.J.H., 1965. The caldera analogy in selenology. *Ann. N.Y. Acad. Sci.*, Vol. 123, p. 843.

Meen, V.B., 1950. Chubb crater, Ungava, Quebec. *J. RASC,* Vol. 44, p. 169.

Meen, V.B., 1957. Chubb crater – a meteor crater. *J. RASC,* Vol. 51, p. 137.

Millman, P.M., B.A. Liberty, J.F. Clark, P.L. Willmore, and M.J.S. Innes, 1960. The Brent crater. *Pub. Dom. Obs.*, Vol. XXIV, p. 1.

Read, H.H., 1956. *The Granite Controversy.* Thos. Murphy & Co., London.

Robertson, P.B., 1968. La Malbaie structure, Quebec – a Paleozoic meteorite impact site. *Meteoritics,* Vol. 4, p. 89.

Rondot, Jehan, 1968. Nouvel impact météoritique fossile? La structure semi-circulaire de Charlevoix. *Can. J. Earth Sci.*, Vol. 5, p. 1305.

Shoemaker, E.M., 1960. Penetration mechanics of high velocity meteorites illustrated by Meteor Crater, Arizona. *Int. Geol. Cong.*, XXI Session, Copenhagen, Rept. XVIII, p. 418.

Shoemaker, E.M., 1962. Impact mechanics at Meteor Crater, Arizona. *The Moon, Meteorites and Comets, The Solar System,* Vol. IV, B.M. Middlehurst and G.P. Kuiper (Ed.), Univ. of Chicago Press, Chicago, p. 301.

St. John, B.E., 1968. Paleolacustrine arenites in the Holleford meteorite crater, Ontario. *Can. J. Earth Sci.*, Vol. 5, p. 935.

*Gold and Voight (1967) have examined the Mecatina structure and are inclined to interpret it and other similar features to deformation in the gneisses due to a variety of metamorphic processes unconnected with volcanic or impact crater formation. While we can not accept this viewpoint without further evidence we agree that it enhances the controversial nature as well as the scientific interest of the very interesting topographic features listed in the Table.