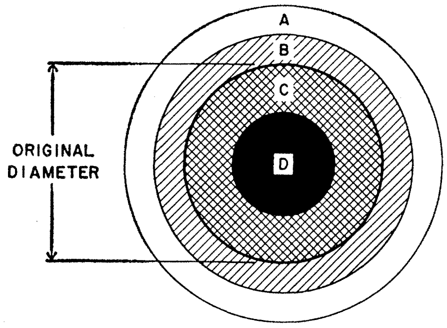


Fig. 2. Schematic cross-sectional cut of a silver coil based on the different strata observed and the conditions indicated by analytical results: *A*, Calcium carbonate redeposited from limestone by the reaction of atmospheric $CO_2$ and water. *B*, Calcium carbonate with AgCl and elements that have diffused out of the original silver. *C*, Silver chloride, metallic silver, and elements that are replacing the original silver. *D*, Remaining original silver.

is limited to speculation. Spectrochemical analysis of loose dirt from one ring indicates the presence of limestone, sand or clay, and alkali in the vicinity of the objects. Corrosion products from the silver show loss on ignition (750°C) to be as high as 30 percent because of water and other volatiles such as $CO_2$ from calcium carbonate. X-ray diffraction patterns identified AgCl as a major phase in several strata. AgCl was confirmed by dissolution in $NH_4OH$ and reprecipitation in $HNO_3$. An interpretation of the strata shown in Fig. 2 is as follows:

*A* (light yellow) is calcium carbonate redeposited from limestone by the reaction of atmospheric $CO_2$ and water. Sand or clay is present in small amounts. Only traces of sodium were detected.

*B* (black to violet) is calcium carbonate with AgCl and elements (Au, As, Bi, Pb, Sn, and Zn) that have diffused outward.

*C* (violet) is AgCl and silver metal with calcium and other impurities (Mg, Si, Al, Fe, Ni, and others) that have diffused inward and replaced the original silver.

*D* (metallic) is the remaining silver.

The surfaces of the objects are not uniform and show areas that are black, grey-violet, and yellow. Since they are not uniformly yellow, indications are that the AgCl diffuses to the surface, for the most part, at a faster rate than the calcium carbonate is deposited. It can only be assumed that AgCl is formed by the metal gradually replacing the $Na^+$ ion in the NaCl that may be present, with the resultant alkali products being leached away. This is an unusual reaction that evidently requires a long period of time for completion.

Some conclusions may be drawn about the purity and composition of the original silver by correcting the analytical results of the remaining silver core (Fig. 2, *D*) for changes due to contamination and diffusion of the elements. To make allowances for differences in diffusion rates is beyond the scope of this study. Table 1 is a summary of results obtained and shows the composition of the purest silver found (almost 99 percent) and the concentration range for all objects. The evidence is that attempts were made to refine the silver as pure as practical and that copper was added to harden the metal and lower the melting point. The other elements are residual impurities. The compositional range is wide enough to suggest that the objects were made at different times with different starting batches.

Table 1. Chemical composition of silver jewelry from Ur. Results are given in percentage by total weight. ND, not detected. (Ca, Mg, Sr, and Si were present but are not reported as part of the original composition because the major source was traced to contamination from diffusion and other processes.)

| Element | Purest object found (Fig. 1, item 3) | Concn. range for all objects |
|---|---|---|
| Ag | Major | Major |
| Cu | 1. | 1. – 5. |
| Pb | 0.1 | 0.01 – 0.5 |
| Au | 0.05 | 0.02 – 0.1 |
| Sn | ND | 0.1* |
| Zn | ND | 1.* |
| As | ND | ND – 0.2 |
| Bi | 0.1 | 0.02 – 0.2 |
| Fe | 0.01 | 0.01 – 0.05 |
| Al | 0.0003 | 0.0003 – 0.001 |
| Ti | ND | ND – 0.005 |
| Ni | 0.002 | 0.001 – 0.02 |
| Cr | ND | ND – 0.01 |
| Mn | ND | ND – 0.01 |
| B | ND | ND – 0.01 |
| V | ND | ND – 0.02 |
| Na | ND | ND – 0.05 |

* Present in one object only (Fig. 1, item 1).

Although spectrochemical analyses do not detect nonmetallic elements, it can be assumed that they were negligible. In purity the silver compares favorably with present-day sterling (92.5 percent) and, no doubt, could easily be worked into various objects. The objects predate most of our information about silver metallurgy of ancient Mesopotamia, which has been obtained from cuneiform tablets of the 3rd millennium B.C. Just what government controls existed at the time the objects were made is not known; however, our study shows that by the Early Dynastic Period III the purity of silver for jewelry was high and well within requirements known from translations of a later period (*3*).

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3. Supported by the National Institutes of Health research grant RG 7391 to one of us (M.L.).

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## Gravity and Magnetic Anomalies of the Sierra Madera, Texas, "Dome"

Abstract. *A geophysical traverse across the Sierra Madera "Dome" indicates a negative gravity anomaly of 1½ milligals over the zone of brecciation in the center and a residual positive anomaly of ½ milligal associated with a positive magnetic anomaly of 25 × $10^{-5}$ oersted to the southeast of the zone of brecciation. Areal surveys are needed before any definite conclusions can be drawn concerning the origin of Sierra Madera. However, gravity and magnetic data can be extremely valuable in establishing criteria for classifying terrestrial and lunar features according to meteoritic and cryptovolcanic origin.*

The origin of the Sierra Madera "Dome" (in Pecos County, Texas), 275 m high, has been ascribed by various authors to the impact of a meteor (*1*). In August 1962, the gravity-magnetic traverse indicated on the geologic map (Fig. 1) was completed by a field crew from Texas Instruments. Figure 1 also shows the topographic, gravity, and magnetic profiles along the traverse and a schematic cross section of the surface geology. A negative gravity anomaly of about 1½ milligals is centered over the zone of brecciation associated with the feature (Fig. 1, top). A local positive residual gravity anomaly of about ½ milligal appears on this profile, coinciding with the east flank of the zone of brecciation (Fig. 1, bottom). This gravity value is associated with a positive magnetic anomaly of about 25 gammas ($25 \times 10^{-5}$ oersted) that is offset slightly to the west (Fig. 1, bottom). The depth of the body or mass that gives rise to these anomalies on the flank of the zone of brecciation can only be estimated roughly because the gravity and magnetic data pertain to a single traverse. On the basis of these data, however, a maximum depth of about 150 m may be assumed.

These data are in agreement with the results of reconnaissance work conducted by Lowman (*2*), who made observations of 11 magnetic stations within the zone of brecciation and at nine additional stations in the remainder of the elevated area. In general, his values are low for the zone of brecciation, but he obtained some higher values near the eastern boundary. The higher values fall within the general area of the residual positive magnetic anomaly shown in the profile (Fig. 1). Although the available geophysical data and the presence of shatter cones in the breccia are suggestive, more extensive surveys must be made before definite conclusions can be reached about the origin of Sierra Madera and the igneous or meteoritic nature of the body at depth.

Chemical composition, in terms of the amount and type of iron and nickel in a meteorite, determines whether a magnetic survey will be useful in studying an earth feature to determine its terrestrial or extraterrestrial origin. In addition, the extent to which the meteorite has disintegrated or fragmented upon impact determines the nature, size, and shape of the fragments. This, in turn, governs the probability of their being detected by magnetic surveys. Similarly, there are also limitations to the usefulness of gravity surveys, although such surveys might appear to be ideal because the impacting meteorite has a higher density than the impacted material. If the meteoritic fragments are sufficiently large, they can be detected by means of a gravity survey, and they yield a positive gravity anomaly. If they are very small, however, they are difficult to detect by gravity methods. On the other hand, because of the typically high impact velocities, a zone of highly shattered material is always produced in the impact area. This could explain the well-defined negative gravity anomalies associated with the zones of brecciation of the Sierra Madera and of other features known or suspected to be of meteoritic origin. These anomalies are summarized in Table 1. Excellent examples of this phenomenon have been noted by Innes (*3*), who shows that negative gravity anomalies of 1 to 2 milligals, 3 to 4 milligals, and about 12 milligals are associated with the Canadian Holleford, the Brent, and the Deep Bay features, respectively. The amplitude of these anomalies may be somewhat less than is indicated in Table 1 because the gravity data were not obtained to sufficient distances beyond the edges of the craters to define accurately the regional gravity. However, there is good correlation between the anomalies and the zones of extreme brecciation that are associated with the three features. In addition, there is some indication of a small residual positive gravity anomaly of less than 1 milligal, local in extent, for the Holleford and Brent craters. These local anomalies may be related to larger fragments of the meteorite that were possibly responsible for the extensive brecciation and the

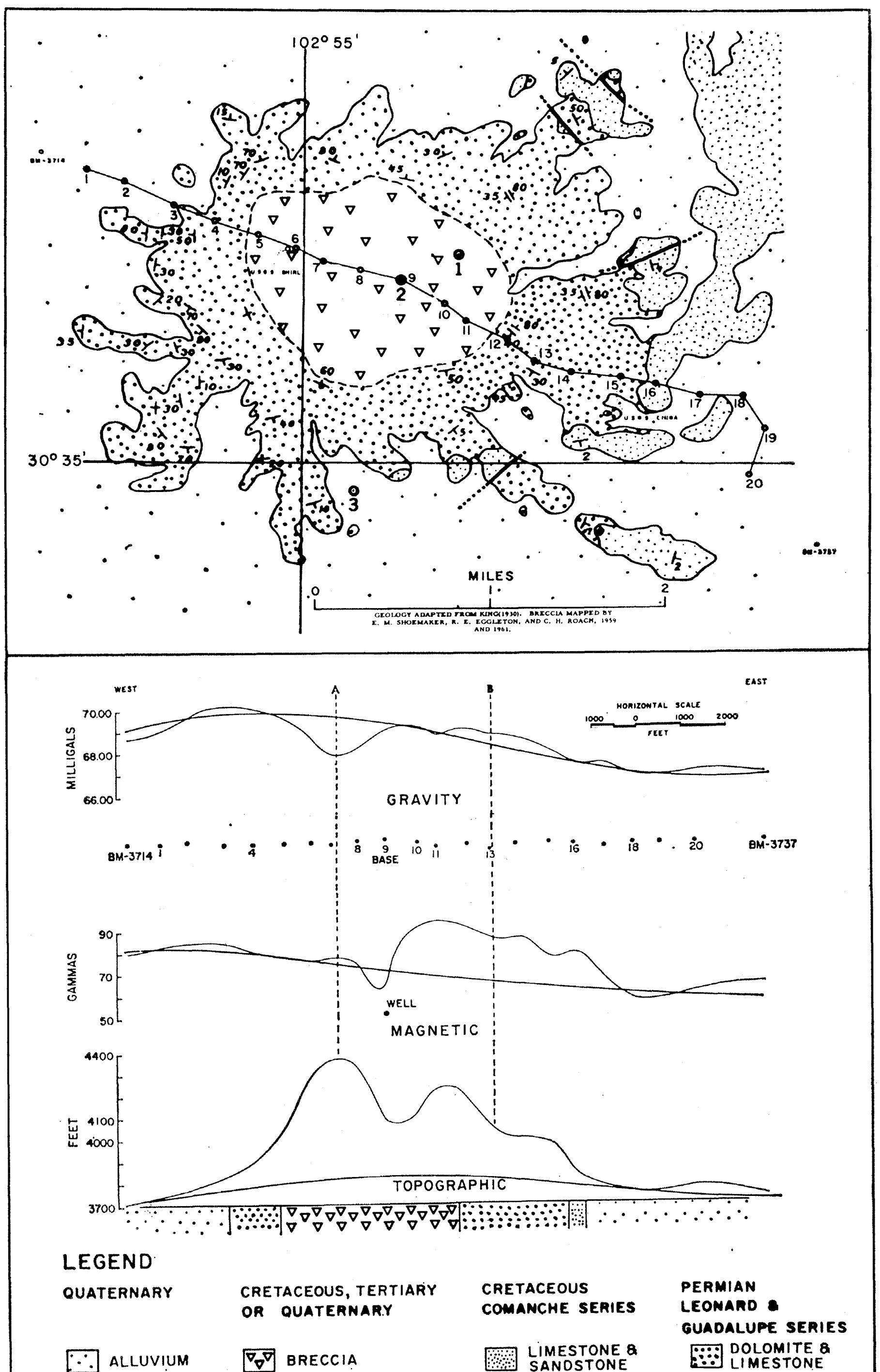


Fig. 1. Geologic and geophysical data for the Sierra Madera, Pecos County, Texas.

Table 1. Gravity anomalies possibly attributable to meteoritic origin of terrain features.

| Location | Amplitude (milligals) Major negative anomaly | Minor residual positive anomaly | Reference |
|---|---|---|---|
| | *Canada* | | |
| Canadian Holleford | −(1–2) | 1 | (*3*) |
| Brent | −(3–4) | 1 | (*3*) |
| Deep Bay | −12 | | (*3*) |
| | *United States* | | |
| Arizona | −¾ | ¼ | (*4*) |
| Texas | −1½ | ½ | |

associated large negative gravity anomalies.

Harding (*4*) has made a gravity survey over the Barringer (Arizona) meteorite crater and has combined the data with results of a vertical-component, magnetometer survey made by J. J. Jakowski. Again, there is a regional negative anomaly of about ¾ milligal, centered over the crater and the zone of brecciation. There is also evidence of a local positive residual gravity anomaly of about ¼ milligal on the southwest flank of the crater. This could be caused by a fairly large fragment of the original meteorite which did not shatter or vaporize. Additional evidence in support of this assumption is found in the 30-gamma positive magnetic anomaly associated with, although offset slightly from, the gravity anomaly. Magnetic data are very useful as corroborative evidence in interpreting the geologic significance of gravity data. Consequently, it is desirable to conduct both magnetic and gravity surveys over features of this type in order to establish criteria for determining their terrestrial or extraterrestrial origin.

Data obtained within the next few years by unmanned and manned lunar missions will increase our understanding of the origin and history of the moon. How much information we obtain and how correctly we interpret the data that we do obtain will depend upon our ability to determine early in the lunar-exploration program the origin of specific features of the moon's surface. To gain this ability, we must first determine and catalog the geologic and geophysical properties of terrestrial features caused by the impact of meteors. We must also study, in this connection, the characteristics of volcanic and cryptovolcanic features, to establish a valid basis for making terrestrial-lunar comparisons. However, until the formational mechanics of analogous terrestrial features and the effects of various genetic processes on the field of force and on other physical properties are known, we will have no valid basis for making comparisons of this kind, and for interpreting regional or local geophysical data for the moon. Thus, we must understand pertinent terrestrial phenomena before we can hope to make an effective analysis of empirically derived lunar data, as a sound basis for conducting research on the surface of the moon.

Geologists have done much detailed field and laboratory work on terrestrial features that are known or suspected to be the result of meteoritic impact or of volcanic and cryptovolcanic processes. This work has resulted in the proposal, and general acceptance, of a number of basic geologic criteria for classifying such features. These criteria pertain to such diverse factors as topography, brecciation (on both a macro and a micro scale), intense shearing, and the presence of shatter cones, glass, and coesite or other minerals that form at high pressures. At present, no similar set of criteria based on geophysical data is generally recognized.

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12 August 1963

## Astaxanthin in the Cedar Waxwing

Abstract. *The pigment on the secondary feathers of the cedar waxwing* (Bombycilla cedrorum) *is deposited as an amorphous layer upon a supporting medullary structure. The pigment was extracted with alkali and analyzed by chromatographic and spectrophotometric methods. The results indicate that the pigment is astacene (3,3′,4,4′-tetraketo-β-carotene), the oxidation product of astaxanthin.*

Among the passerine birds, one of the more unusual and conspicuous deposits of pigment occurs in the cedar waxwing, *Bombycilla cedrorum*, where it occurs in the form of a waxy, red

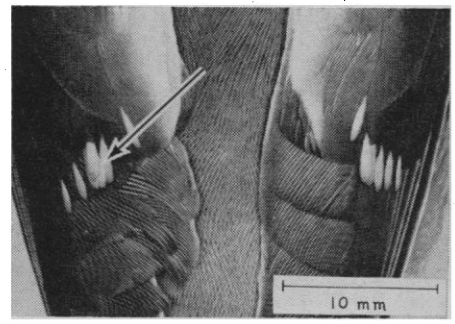


Fig. 1. Dorsal view of a cedar waxwing. Arrow points to pigmented tips on secondary feathers.

appendage on the tips of the secondary wing feathers (Fig. 1). The appendage has a waxy sheen, and is characterized by a bright dorsal and a dull ventral surface. Arvey (*1*) reports that the pigment occasionally occurs on the tips of the rectrices of this species. In a closely related form (*B. garrula*), the tips may be yellow. Tips are reported with about equal frequency in both sexes but are not found on all individuals in a population. Dwight (*2*) and Phillips (*3*) report the presence of the tips in the juvenal plumage. Arvey (*1*) states that available data show that the young of *B. cedrorum* lack the tips.

The object of this investigation was to determine the morphological relationship of the pigment to the feather, and the chemical nature of the pigment itself. To determine the morphological relationship of the feather and the pigment, tips were embedded in gelatin, sectioned on a freezing microtome, and prepared as dry mounts. A photomicrograph of a tip is shown in Fig. 2. The red pigment appeared as an amorphous cortical layer superimposed on a more structured medullary layer. Surrounding both layers was a transparent cuticle. The tip is essentially the flattened extension of the central rachis, similar to that in *B. garrula* as shown by Stieda (*4*). The structure is unique in feathers.

The nature of the pigment was determined by the method of Fox (*5, 6*). The pigment was not extractable in cold acetone, cold alkaline methanol, or hot pyridine. This may have been due to the impervious nature of the cuticular covering. Wingtips from the feathers of twelve birds were placed in hot (90°C) alkaline methanol. The hydrolyzate from this hot alkaline methanol was yellow-orange in color. The hydrolyzate was centrifuged and the supernatant was collected, diluted, and partitioned with petroleum ether. The