New Rules for AAAS–Newcomb Cleveland Prize

The AAAS–Newcomb Cleveland Prize, which previously honored research papers presented at AAAS annual meetings, will henceforth be awarded annually to the author of an outstanding paper published from September through August in the Reports section of *Science*. The first competition year under the new rules starts with the 3 September 1976 issue of *Science* and ends with that of 26 August 1977. The value of the prize has been raised from $2000 to $5000; the winner also receives a bronze medal.

To be eligible, a paper must be a first-time presentation (other than to a departmental seminar or colloquium) of previously unpublished results of the author's own research. Reference to pertinent earlier work by the author may be included to give perspective.

Throughout the year, readers are invited to nominate papers appearing in the Reports section. Nominations must be typed, and the following information provided: the title of the paper, issue in which it is published, author's name, and a brief statement of justification for nomination. Nominations should be submitted to the AAAS–Newcomb Cleveland Prize, AAAS, 1515 Massachusetts Avenue, NW, Washington, D.C. 20005. Final selection will rest with a panel of scientists appointed by the Board of Directors.

The award will be presented at a session of the annual meeting at which the winner will be invited to present a scientific paper reviewing the field related to the prize-winning research. The review paper will subsequently be published in *Science*. In cases of multiple authorship, the prize will be divided equally between or among the authors; the senior author will be invited to speak at the annual meeting.

Reports

Mineral-Produced High-Pressure Striae and Clay Polish: Key Evidence for Nonballistic Transport of Ejecta from Ries Crater

Abstract. *Recently discovered mineral-produced, deeply incised striae and mirror-like polish on broken surfaces of limestone fragments from the sedimentary ejecta of the Ries impact crater of southern Germany are described. The striae and polish were produced under high confining pressures during high-velocity nonballistic transport of the ejecta mass within the time span of the cratering event (measured in terms of seconds). The striae on these fragments were produced by scouring by small mineral grains embedded in the surrounding clay matrix, and the polish was formed under the same condition, by movements of relatively fragment-free clay against the fragment surfaces. The occurrence of these striae and polish is key evidence for estimating the distribution and determining the relative importance of nonballistic and ballistic transport of ejecta from the shallow Ries stony meteorite impact crater.*

The Ries crater of southern Germany is the largest of the well-preserved impact craters on the earth. It is 25 km in diameter, and was probably produced by impact of a stony meteorite (*1*). It is a very shallow (depth-to-diameter ratio, 1/33) multiring basin; recent data suggest that during the impact event nonballistic transport of ejecta by the roll-glide (Wagner) mode greatly dominated ballistic transport (*2*). Thus it appears that the basic cratering mechanism for producing such a very shallow crater may be notably different from that for producing a bowl-shaped crater, such as the Meteor Crater of Arizona. Because the correct choice of a cratering model and knowledge of the mechanism of ejecta transport are fundamental to predicting ejecta distribution so that detailed lunar sample data can be related to important lunar events, criteria for determining the relative importance of nonballistic and ballistic transport of ejecta from shallow multiring basins would be important to investigators interested in lunar science and planetary geology. New data obtained since the summer of 1975 suggest that the Ries is the best cratering model for large planetary multiring basins, such as the Imbrium and Orientale basins on the moon and the Caloris and other shallow basins on Mercury and Mars (*2*).

Among several criteria previously cited as evidence for nonballistic ejecta transport are striated bedrock surfaces and striations, gouges, and scour marks found on boulders, pebbles, and small fragments in the varicolored sedimentary ejecta (bunte Breccie) of the Ries (*2*). These marks, millimeters to centimeters wide and as much as 2 cm deep, were produced by rock fragments moving against each other or against the bedrock over which the ejecta mass was transported. Such effects, as well as the plastic deformation observed in limestone and sandstone concretions in the ejecta (*2*), suggest that these ejecta masses were transported by roll and glide under high confining pressures on and along the ground surfaces, following preexisting topography. These features and the mixing of ejecta by the roll and glide motion serve to distinguish nonballistically from ballistically transported ejecta. The latter are airborne, hence free of confining pressure, and the fragments so transported are free of striations produced by relative movements within the ejecta mass.

Striated pebbles in the Ries varicolored sedimentary ejecta were noted by Sauer as early as 1903 [Sauer, quoted by Branco (*3*); see also Sauer (*4*)]. At that time investigators were trying to distinguish the Ries varicolored sedimentary ejecta from glacial moraine. In the communication quoted by Branco, Sauer noted that pebbles and sand grains in the varicolored ejecta can be detached from the clayey matrix in most cases rather easily, leaving a shiny impression, as if they were surrounded by concave mirrors. Sauer, however, did not report or notice the mirror polish on the pebbles and sand grains themselves.

I recently discovered another type of striae, which are much finer than the rock-produced striae and scour marks discussed above. These were produced by the movement of mineral grains along rock surfaces during ejecta transport. The striae are usually less than 50 μm in width, are closely spaced, and are on the order of hundreds of micrometers in length. They occur on the surfaces of rounded pebbles and on freshly broken and fractured surfaces, in contrast to the rock-produced scour marks, which occur mostly on the surfaces of well-rounded to subrounded boulders and pebbles. Without exception, the mineral-produced striae occur on surfaces that are polished. These fine striae and the associated polish are strictly limited to the surficial layers—a few micrometers to millimeters thick—of fragments. The striated limestone fragments are free of fractures or any other signs of shock deformation. Hence the striae are strictly products of ejecta transport and not related to shock metamorphism. They are unlike any striae produced by any other geological processes.

In several varicolored sedimentary ejecta deposits in the Ries that I have studied, a few percent of the limestone fragments are either striated or polished or both. It is probable that careful examination in the laboratory of fragments segregated from samples of varicolored sedimentary breccia with clay matrix may disclose fragments with evidence of striae and polish.

Occurrence and description. Mineral-produced striae on limestone fragment surfaces with various degrees of polish have been found in varicolored ejecta deposits from many quarries in the Ries—for example, the Teich quarry of Gundelsheim 7.5 km east-northeast of the crater rim, the Bschor quarry near Ronheim just outside the southeast rim of the crater, and the Harburg south quarry about 1.5 km south of the Bschor quarry. They have also been found on limestone fragments from drill core samples of sedimentary ejecta drilled in the summer of 1976 at Otting (3 km east of the crater rim) and at Itzing (5 km east-southeast of the crater rim). The location farthest from the crater center where striae on limestone fragments have been found is Altenburg, about 17 km south-southwest of the Ries crater rim.

The striae and polish are found on fragments ranging in size from meters to centimeters. Such features may occur on all surfaces of a fragment, on only a few corners, or on one surface.

The trends of striae on different surfaces of a specimen are generally in different directions. Often there is more than one set of striae crisscrossing on the same surface. A fragment may be predominantly striated or predominantly polished, or may have surfaces showing varying degrees of development of striations and polish between these extremes. Luster of the striated surfaces ranges from dull to waxy or greasy to mirrorlike.

Figure 1a shows a Malm (White Jura) limestone fragment, embedded in the varicolored sedimentary ejecta with typical clay-rich matrix. Figure 1b shows an angular limestone fragment with closely spaced parallel striae on all surfaces (see also Fig. 1d). The angular limestone fragments in Fig. 1c are highly polished and shine like mirrors.

Figure 1e shows a stereoscopic scanning electron microscope (SEM) view of mineral-produced striae and polish. Fresh surfaces of the limestone are porous, and the areas under the striae are also porous. Polished areas are not porous, however; they are featurelessly smooth or are decorated either by extremely fine striae of submicrometer width or by broad depressions or troughs. Most often, elongated areas of different degrees of polish are interspersed with striae a few to 20 μm wide.

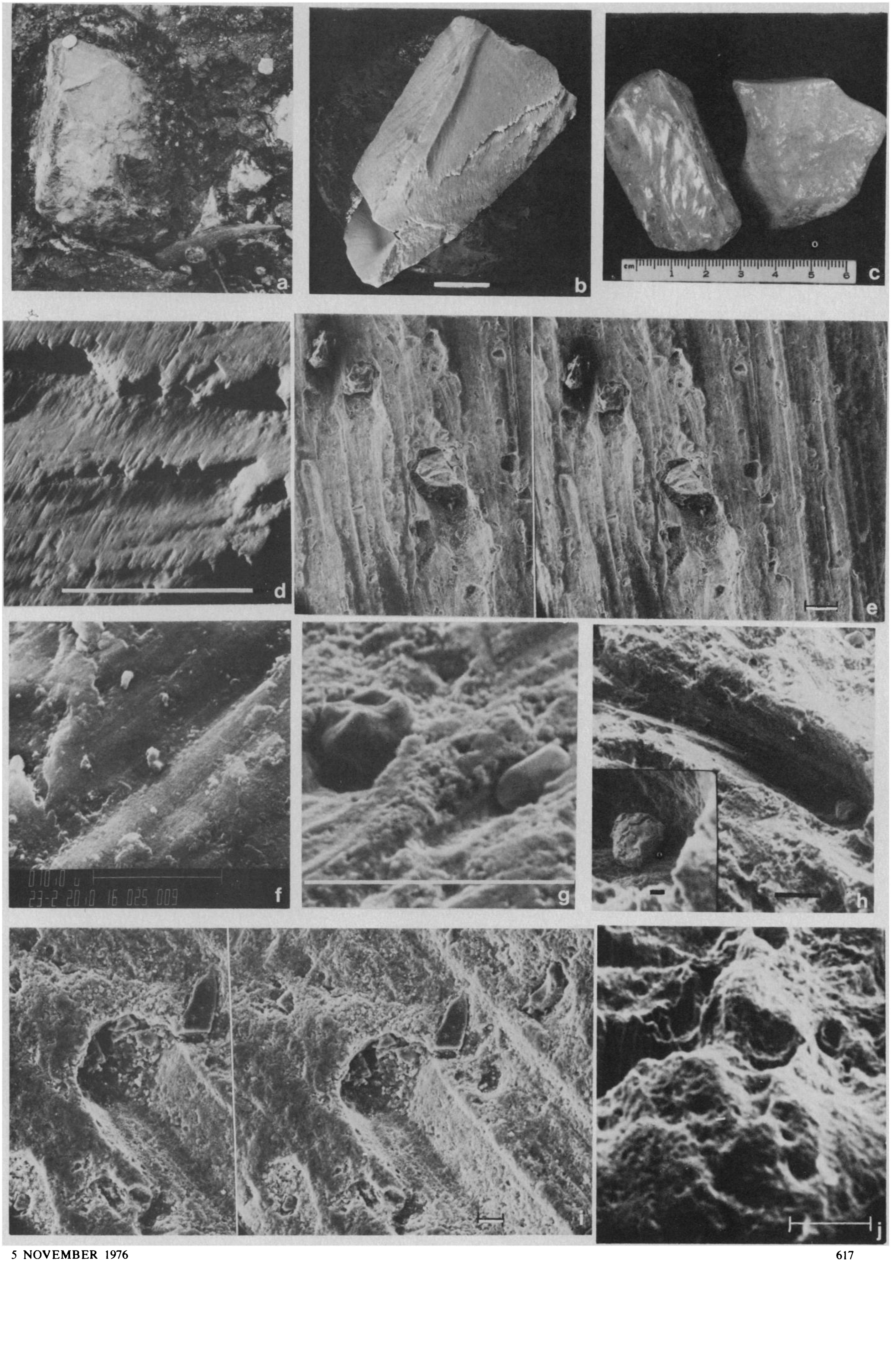
Figure 1f shows a mirrorlike polished surface greatly magnified under the SEM. The original pores in the polished areas appear to have been filled by extremely fine grained submicrometer particles removed by abrasion from surrounding areas and pressed into the pores. These surfaces are somewhat similar to the Beilby layer (*5*), a submicrometer powdery surface layer produced by the polishing of metallurgical or mineral specimens.

The characteristics of the mineral-produced striae vary. Some are simple grooves and U-shaped troughs open to the surface on both entry and exit. Others are sharply V-shaped; many of these terminate abruptly where the mineral grains either dug into the substrate and were lodged there, or were broken and plucked off, leaving a sharp pinhead-shaped indentation. Such V-shaped striae with sharp terminal points are shown in Fig. 1d.

In Fig. 1e several striae show the mineral grains that produced them still lodged in their terminal positions. The minerals were identified with an energy-dispersive analyzer attached to the SEM. Note also in Fig. 1e the abundance of sharp depressions and indentations on the striated surface where mineral grains are no longer present. In several samples, the mineral grains have been pressed into the limestone so that the upper surfaces of the mineral grains are level with the striated surfaces. Figure 1g shows a close-up SEM photograph of such a surface. A single crystal of quartz has made a clear track, and another quartz fragment has made a deep indentation and buried itself in the limestone. [Note the porous areas of the limestone as compared to the smooth, polished, and filled (no longer porous) areas under the striae.] Figure 1h shows a broad deep stria containing a grain of limestone. The rolled and layered surface of this grain (inset, Fig. 1h) suggests kneading and plastic deformation produced under confining pressure while embedded in the clay that surrounded the limestone fragment.

In many cases, the minerals not only have made the striae, they appear to have dug into the limestone substrate and bored a hole in it. Figure 1i shows an example of such a tunnel-like termination of a stria.

Fig. 1 (opposite page). (a) Exposure of varicolored sedimentary ejecta at the Teich quarry of Gundelsheim. Note the large angular fragment of Malm (White Jura) limestone. The fresh fracture at the upper left corner has a smooth, shiny polished surface with parallel, sharply etched fine striae. The coin at top of the limestone is 2 cm in diameter. (b and c) Photographs of angular limestone fragments from the varicolored sedimentary ejecta. (b) Angular fragment of Malm limestone with a waxy surface and closely spaced mineral-produced pressure striae on all sides of the specimen. The striae run in different directions. The lower left corner was cut off for SEM study; see (e). From Bschor quarry, Ronheim. Scale bar, 1 cm. (c) Highly polished angular fragments of limestone. The reflecting areas (white) are only part of the polished surfaces that cover the entire specimen. From Harburg south quarry. (d) Photograph of well-developed sharply incised striae. Note the striae that cross the terraced fresh fractures of the limestone. Movement of the minerals that produced the striae was from lower left to upper right, terminating in the pinhead-shaped broad end of the striae. Minerals still lodged at the ends of these striae are present but not visible in this photograph; see (e). Scale bar, 1 cm. (e) Stereoscopic SEM photographs showing the details of the mineral-produced deeply incised striae. Two quartz grains in their terminal position are located in the upper left. A large K-feldspar grain is embedded in the limestone near the center. The striated areas are white and the smoother polished streaks dark. Note also other vacant pits and indented areas left by similar mineral grains. Scale bar, 100 μm. (f to h) SEM photographs. (f) Typical very highly polished limestone surface with smooth submicrometer striae trending from upper right to lower left. (g) Single crystal of quartz pressed into the limestone at the end of an incised stria running from lower left to upper right. Another quartz fragment to the left was pressed into the limestone below the striated surface and made a deep indentation. Scale bar, 100 μm. (h) Broad deep groove probably made by a cluster of mineral grains. Scale bar, 10 μm. (Inset) Enlarged view (scale bar, 100 μm) of the grain of limestone ($CaCO_3$ with trace of Si and Fe) left in the trough. (i) Stereoscopic SEM views of a stria ending in a tunnel-shaped opening, suggesting that the mineral fragment not only grooved the surface but actually drilled into the limestone substrate. Note the porous granular surface of the limestone. Scale bar, 10 μm. (j) SEM photograph showing deep parallel striae of different depths. The two double-lined pits or indentations (upper right) each contain an inner circular ridge produced by a small grain as a result of plastic deformation, after the large pit was produced by a large grain. Scale bar, 100 μm.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Further evidence that the high confining pressure allowed the mineral grains to be pressed into the limestone or to make deep tracks and then be half-buried in the limestone is shown in Fig. 1j; two indentations have concentric inner walls, indicating plastic deformation produced first by a large grain, then by a smaller grain.

So far the most common mineral grains found to have produced the pressure striae are quartz. Other mineral grains identified are K-feldspar, pyrite, and aggregates of calcite.

Interpretation. The origin of these striae on limestone fragments and the conditions under which they were formed are relatively easy to determine. The remnant mineral grains in the terminal positions of striae give proof that the striae were produced by scouring by mineral grains. The polish was produced by movement of fragment-poor clay matrix against the surfaces. The observation that relatively deep striae in porous substrates and shallower striae in smooth polished surfaces are juxtaposed (Fig. 1, e and g) clearly indicates that the mineral grains that formed the striae were embedded in clay; thus, the striae and polish were produced simultaneously by the relative movement between the limestone fragment and the adjacent clay matrix with its variable content of mineral grains. The accompanying local plastic deformation (Fig. 1, h and j) indicates that these striae must have been produced at least locally under extremely high confining pressure. The fact that such pressure striae and polish are found on angular fragments shows that the pressure striae and clay polish were produced within the time span of the cratering event after the fragment was broken up by the impact, that is, within a time span measured in terms of seconds.

It is evident that the development of the mineral-produced striae and polish on surfaces freshly fractured during the impact event depended on the nature of the clay matrix and the mineral grains it contained. In field studies in the summer of 1976 I found that striated and polished fragments are more common in parts of the varicolored ejecta with a clayey matrix of purple Keuper and gray Dogger shale, abundant quartz grains, and Malm limestone fragments. Striated and polished fragments are generally not found in large blocks of Dogger or Lias gray shale free of sand-size grains (where plastically deformed concretions are found) or in Tertiary sandy clay. The shale blocks do not tend to mix intimately with Malm limestone or quartz grains from the Mesozoic sandstones or the basement crystalline rocks.

The order of magnitude of the high confining pressure can be only roughly estimated from the nature of plastic deformation in micaceous ferruginous sandstones in the Dogger gray shales found within meters of these striated limestone fragments. The deformational features detectable in these concretions are ruptures and weak kink bands in mica, suggesting that the deformation is low and is of the slow-strain-rate type. The differential pressure required to produce such deformation under confining pressures is probably in excess of about 2 kbar and may be as much as 4 kbar, appreciably greater than the normal compressive strength of these concretions. Nevertheless, the confining pressure exerted by the enclosing clay matrix must have been very great (many times the differential pressures) since the entire process of deformation lasted only a few seconds. Such confining pressures must have been present to produce the plastic flow locally and essentially on the surficial layer of the limestone fragments. It would be difficult if not impossible to explain the observations shown in Fig. 1, h and j, if the limestone did not behave plastically locally.

If these pressure striae and clay polish can be reproduced experimentally in the laboratory, then they may be used not only for estimating the velocity of the nonballistic ejecta transport under confining pressures but also the duration of the cratering event.

Implications. Sand-size fragments from every varicolored sedimentary ejecta mass at the Ries can be examined for the presence of high-pressure mineral-produced striae and clay polish. With this key criterion, the distribution and abundance of nonballistically and ballistically transported ejecta can be delineated, leading to a better understanding of the detailed development of the Ries crater.

There are no limestones on the moon or other planetary surfaces. But such striae may occur on other rock types, where they may be more difficult to identify. Similar striae may occur on 14053, a basalt, and 14047, a breccia, two unshocked lunar samples returned from Fra Mauro by the Apollo 14 mission.

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References and Notes

1. A. El Goresy and E. C. T. Chao, *Earth Planet. Sci. Lett.* **31**, 330 (1976).
2. E. C. T. Chao, *Fortschr. Mineral.*, in press.
3. W. Branco, *Das vulcanische Vorries und seine Beziehungen Zum vulcanischen Riese bei Nördlingen* (Preussischen Akademie der Wissenschaften, Berlin, 1903), pp. 105–106.
4. A. Sauer, *Jahresber. Mitt. Oberrhein. Geol. Ver.* **13**, 115 (1924).
5. C. S. Barrett, *Structure of Metals* (McGraw-Hill, New York, 1952).
6. I am indebted to W. Horn of the Max-Planck-Institut für Kernphysik of Heidelberg, Germany, and to R. Larson of the U.S. Geological Survey for the SEM photographs. I thank C. Thompson and R. McKinney of the U.S. Geological Survey for preparing the photographs used in this report. R. Hüttner, of the Geological Survey of Baden-Württemberg, Germany, called my attention to Sauer's earlier observations.

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Hydra hymanae: Regulation of the Life Cycle by Time and Temperature

Abstract. Hydra hymanae, *a hermaphroditic freshwater coelenterate, reproduces asexually at 24°C and sexually at 15°C. The appearance of gonads begins 12 days after transfer from 24° to 15°C and is complete 35 days after the temperature transition. Testes appear before eggs. Fifty percent of the mature embryos maintained at 15°C hatch by day 61, but they have a low level of survival. Fifty percent of the mature embryos pretreated for from 5 to 25 days at 4°C hatch by about day 45, and these have a high level of survival. Embryos maintained at 4°C for longer periods (55 to 85 days) accumulate in a prehatching state and hatch with a high degree of synchrony approximately 7.5 days after return to 15°C. Populations derived from newly hatched polyps are refractory to sex induction for approximately 120 days. The system is well adapted to ensure a regular alternation of reproductive modes in the natural environment.*

Both environmental and intrinsic factors have been implicated in the control of reproduction in various species of *Hydra* (*1, 2*). I present here evidence that the life cycle of *H. hymanae* is regulated by the interaction of the environmental temperature with an endogenous component related to the age of the population.

The stock used was derived from a few asexual polyps collected from Winooski Pond near the campus of the University