area of the right valve (Fig. 1*a*). Other closed valves were pried open, revealing preserved soft parts in several specimens. The soft parts were the chitinous appendages: legs, antennae, maxilla, mandible, for the most part disarticulated; some were shrivelled from desiccation.

Other complete valves were examined with transmitted light to detect possible preservation of the soft parts. Remains of appendages were found in other specimens of *Paracyprideis pseudopunctillata* (Fig. 1, *b* and *c*) and in *Normanicythere concinella* (Fig. 1*d*) and an immature specimen of *Echinocythereis*. In most instances, however, the remains were jumbled in the anterior or ventral part of the valves, as can be seen.

The ostracods with these mummified remains were found in samples from only two localities: locality *A* (Fig. 1), a raised beach ridge that is exposed in a vertical section by a wave-cut escarpment just southwest of Barrow Village; and locality *B*, a sampled core hole in Elson Lagoon, the material examined coming from 5.2 m below the bottom of the lagoon. The possibility of contamination by sloughing of Recent material is ruled out.

The samples containing the specimens come from strikingly different depositional environments: The beach-cliff locality, consisting of clean sandy gravels typical of a rigorous nearshore environment, contrasts with the silts and silty sands from which the Elson Lagoon specimens were picked.

Positive dating of these sections is not yet completed, but on the basis of the stratigraphic position and dates from other sections in the area, it is reasonable to assume that they are at least older than 38,000 years and probably no older than mid-Pleistocene (*1*). Preserved soft parts had been found in marine pelecypods collected from an elevated beach in Greenland (*2*).

We assume that the ostracod specimens were preserved by rapid burial in a cold environment and subsequently frozen, remaining in this state until they were collected. Desiccation may have occurred either before or during the frozen period, so that only chitinous parts of the endoskeleton and appendages remain. The valves being tightly sealed reduced the likelihood of decay.

As a result of this discovery, closed valves of *Normanicythere concinella* from the Bootlegger Cove Clay (*BC* in Fig. 1), a Pleistocene cold-water deposit in south-central Alaska, were opened: a few specimens yielded disarticulated appendages less well preserved than the northern material.

RUTH A. M. SCHMIDT
1040 C Street, Anchorage, Alaska
PAUL V. SELLMANN
U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire 03755

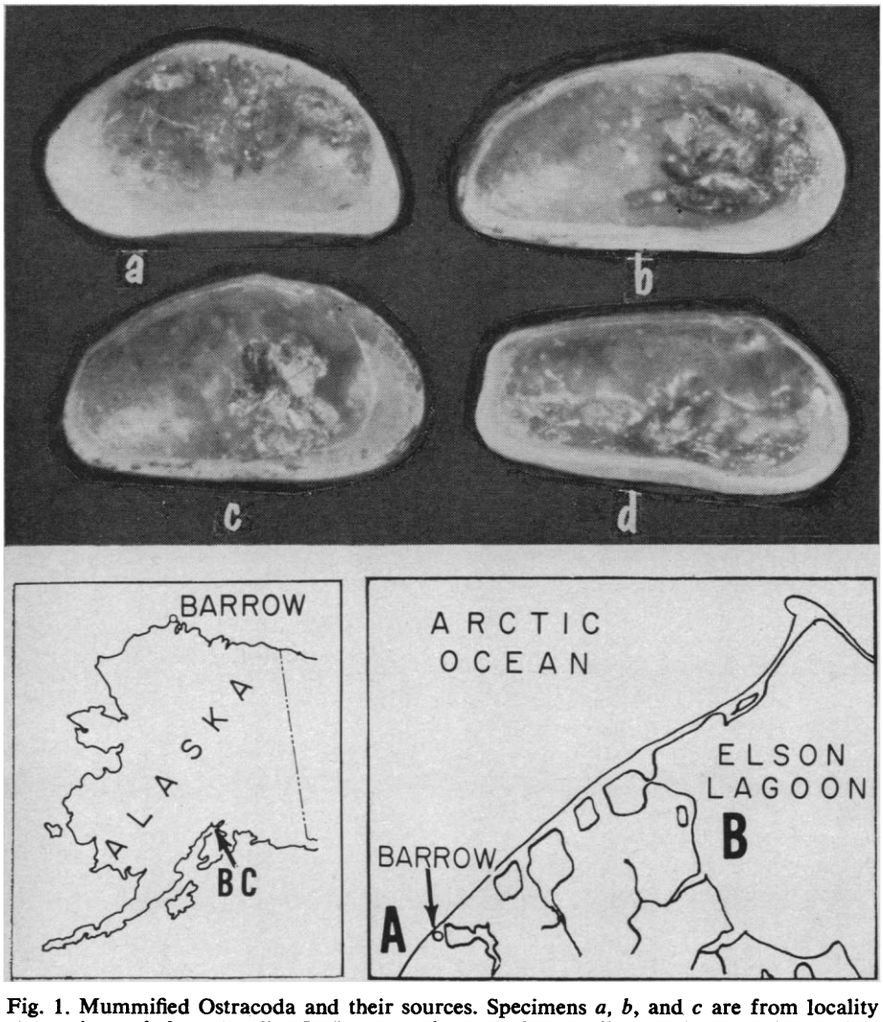

Fig. 1. Mummified Ostracoda and their sources. Specimens *a*, *b*, and *c* are from locality *A*; specimen *d*, from locality *B*. *Paracyprideis pseudopunctillata: a*, interior right valve; *b* and *c*, interior left valves. *Normanicythere concinella: d*, interior left valve. (× 50)

References and Notes

1. P. V. Sellmann, J. Brown, R. A. M. Schmidt, in *Abstr. Intern. Congr. INQUA 7th* (1965), p. 419; J. Brown, *Arctic* **18**, 36 (1965).
2. R. L. Nichols, *Amer. J. Sci.* **259**, 707 (1961); F. P. C. M. van Morkhoven, *Post-Paleozoic Ostracoda* (Elsevier, New York, 1962), vol. 1, p. 29.
3. We thank the U.S. Army CRREL and Arctic Research Laboratory for support, J. Brown and R. I. Lewellen for collaboration and critical comments, and R. B. McLaughlin for photographic assistance.

30 April 1966

Laser as Light Source for Optical Diffractometers; Fourier Analysis of Electron Micrographs

Abstract. *Fourier analysis of electron micrographs has been accomplished under optimum conditions with a gas laser as the light source for an optical diffractometer.*

Klug and co-workers have proposed a novel application of the optical diffractometer to analysis of electron microscopic images and have demonstrated the versatility and power of the technique in detecting structure not apparent on visual examination (*1*, *2*).

The ideal conditions for the production of optical diffraction patterns and the means for their attainment have been established (*3*). Of primary importance are a source of coherent monochromatic light, the use of refracting elements of high quality, and a system

in which all components have their optic axes accurately collinear.

For the particular case in which electron micrograph plates are the objects, optimum results have been achieved when both the average optical density and the contrast of the plate are high. Because of this, the great utility of the optical diffractometer as an adjunct to the analysis of electron micrographs has, in some instances, been limited by the inability of the conventional mercury-arc light source to provide sufficiently intense illumination. Direct visual observation of the diffraction patterns has become most difficult, and photographic recording has occasionally required exposures of several hours' duration. Replacement of the mercury vapor lamp by a gas laser appears to be an ideal solution to this problem. It has been shown by Harburn *et al.* (*4*) that the sharply monochromatic output of a helium-neon laser could be employed to improve the quality of diffraction patterns. Since the instrument available to these investigators operated in more than one mode (multimodal output) where each mode may be considered as an independent, coherent source of light, and, since a single coherent source was required, only a fraction of the total power delivered by the laser could be used. The exposure time could not, therefore, be reduced below that necessary with a conventional light source.

Now that commercial helium-neon lasers with unimodal outputs as high as 50 mwatt are available, we have explored the practicability of using these instruments in a manner which would realize the full intensity of the monochromatic radiation. Three different lasers were tested, namely, Spectra-Physics model 130 (0.3 mwatt) and model 125 (50 mwatt), and Perkin Elmer model 5200 (0.5 mwatt). All operated at 6328 Å. Patterns were recorded on Polaroid 55 P/N film (ASA rating approximately 50).

Although diffraction patterns could be generated by placing objects in the direct beam of the laser, this approach was unsatisfactory for two reasons. First, all diffraction spots have a minimum size given by the diameter of the laser beam which, in our case, was about 1.6 mm; second, only a few diffracting elements in the object can be illuminated by a beam of this width and, as a result, the diffraction maxima are even further broadened. It was, therefore, necessary to use one of the several optical arrangements which have been described (*3*) for production of Fourier transforms. These all require a "point source" of illumination. We have obtained an effective point source by using a converging lens of very short (5 to 10 mm) focal length to focus the bundle of parallel rays delivered by the laser. An aperture approximately 1 mm in diameter, placed to coincide with the "point source," has been useful in shielding the diffractometer proper from stray light.

The usual optical diffractometer design employs two main lenses. Light diverging from a "point source" is collimated by the first lens, and the parallel beam is subsequently focussed by a second lens. The principal focal plane of this second lens is the transform plane, that is, the plane in which the Fourier transform may be observed; the resolution attainable in the transform is directly related to the distance, D, between this lens and the transform plane. For the two-lens diffractometer, D is, of course, equal to the focal length of the second lens. As a result, the resolving power of the instrument may be altered only by photographic enlargement or reduction of the electron microscope plate itself. To suit the resolving power of the diffractometer to the requirements of the particular object under investigation, we have used a single lens diffractometer in which the "point source" and the center of the transform plane are at conjugate foci of a single main lens. Here, D is no longer invariant.

Certain practical points should be noted with respect to the two alternative diffractometer designs. In the double-lens instrument, the object of study is placed between the two lenses; as long as the object is perpendicular to the optic axis, its exact positioning is not critical. This is a particular advantage of the two-lens design and is a direct consequence of the illumination of the object by parallel light; in the single-lens instrument the object is placed close to the lens in nonparallel light, and the magnification of the diffraction pattern will thus vary with the exact position of the object in the beam. Although this is not ideal for the most precise work, the single-lens instrument can provide very good results and is extremely useful for surveying rapidly a large number of objects with different resolution requirements.

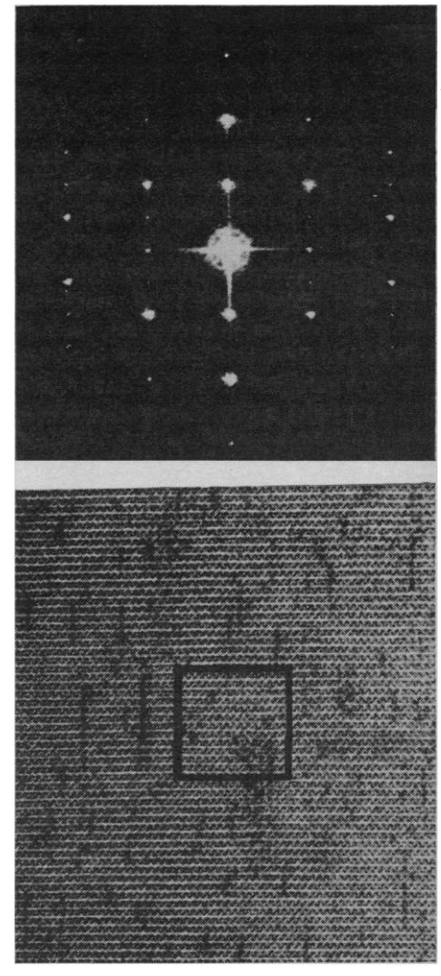

Fig. 1. (Top) Optical diffraction pattern of the electron microscopic plate illustrated in Fig. 1 (bottom). One millimeter on this pattern corresponds to 0.19 mm^{-1} (reciprocal millimeters). (Bottom) Catalase crystal, phosphotungstic acid stain ($\times$ 146,000). The area enclosed in the square was used as the object.

An example of the results obtained with a laser-powered single-lens diffractometer is given in Fig. 1 (top); exposure time was 0.1 second with a Spectra-Physics 130 laser. The electron micrograph plate (*5*) used as the object is illustrated in Fig. 1 (bottom). This is a duplicate of the plate previously analyzed by the use of a conventional diffractometer with mercury-arc light source (*1*). Exposure time for the previously published transform was about 1 minute.

J. E. BERGER
Center for Crystallographic Research, Roswell Park Memorial Institute, Buffalo, New York

C. RICHARD ZOBEL
P. E. ENGLER
Department of Biophysics, State University of New York, Buffalo

References and Notes

1. A. Klug and J. E. Berger, *J. Mol. Biol.* **10**, 565 (1964).
2. J. T. Finch, A. Klug, A. O. W. Stretton, *J. Mol. Biol.* **10**, 570 (1964).
3. C. A. Taylor and H. Lipson, *Optical Transforms, Their Preparation and Application to X-ray Diffraction Problems* (Bell, London, 1964).
4. G. Harburn, K. Walkley, C. A. Taylor, *Nature* **205**, 1095 (1965).
5. Provided by Dr. W. Longley.

6. We thank Dr. R. C. Ziegler, R. F. Schneeberger, and R. E. Kinzly of the Cornell Aeronautical Laboratories for use of their lasers; and Dr. D. Harker for encouragement and suggestions. Supported by American Cancer Society grant IN-54 F-15 (JEB), NIH grant AM-07635 (CRZ), and an employee fellowship to P. E. Engler from Cornell Aeronautical Laboratory, Inc.

13 April 1966

Kyanite-Andalusite Equilibrium from 700° to 800°C

Abstract. *The metastable kyanite-andalusite equilibrium in the Al_2SiO_5 system has been reversed at 700°, 750°, and 800°C at elevated water pressures, with a variety of natural and synthetic kyanites and andalusites as starting materials. Sillimanite, the stable form of Al_2SiO_5 under these conditions, did not appear. The value of the transition pressure at 750°C is 6.6 ± 0.4 kilobars, several kilobars below pressures given by several convergent previous determinations. The Al_2SiO_5 pressure-temperature triple point now indicated lies far from the points found by others. The revised aluminum silicate phase diagram indicates that many rocks crystallized at lower pressures than formerly thought possible.*

The problem of the stability of andalusite, orthorhombic Al_2SiO_5, has been outstanding in petrology for many years. The least dense of the three aluminum silicate polymorphs (3.14 g/cm³), andalusite is considered to be a product of relatively shallow-level rock metamorphism.

The suggestion that andalusite may have no pressure-temperature (*P-T*) stability field relative to the kyanite (3.66 g/cm³) and sillimanite (3.24 g/cm³) polymorphs has been made several times. This concept has its origin in the often weakly recrystallized character of andalusite-bearing rocks, in the notorious slowness of reactions among aluminum silicates in laboratory tests, and in the results of certain early thermochemical studies (*1*).

Khitarov *et al.* (*2*) produced a synthesis diagram for the aluminum silicate system which showed a large andalusite field and a triple point among the three polymorphs at 9.0 kb and 380°C. They used the Bridgman anvil device with external heater and alumina-silica gels as starting material. They did not reverse the boundaries. Bell (*3*) found a diagram very similar to that of Khitarov *et al.* He used an oscillating-piston "simple squeezer" and obtained reversals of the reaction at temperatures as low as 250°C in runs of a few hours duration, by virtue of the enormous acceleration effect of shear on the rate of reaction. He demonstrated that andalusite could be created from natural kyanite and sillimanite under conditions of high shear, in spite of its reputation as an "antistress" mineral (*4*) and, in so doing, showed that andalusite must have a large *P-T* field of stability. Other workers (*5*) using simple squeezer device and gel starting material found kyanite-sillimanite boundaries in agreement with Bell (*2*) and Khitarov *et al.* (*3*) in the range 300° to 800°C.

Precision of location of the Al_2SiO_5 phase boundaries has been limited by the large uncertainty of the pressure conditions between the Bridgman anvils. Many cases are known of phase transitions in which the transition pressure was grossly overestimated on the basis of first determinations with a simple squeezer. Some examples are Cs (II) to Cs (III) (*6*), Ba (II) to Ba (III) (*6*), and the grossularite-quartz reaction (*7*). Newton (*8*) found that the kyanite-sillimanite transition at 750°C was 5 to 6 kb below the simple squeezer determinations. His work was done hydrothermally in the solid pressure piston-cylinder apparatus, with natural minerals for starting material.

All previous experiments indicate that the kyanite-andalusite equilibrium is metastable in the range 700° to 800°C. Nevertheless, since seeding strongly controls aluminum silicate reactions, the kyanite-andalusite reaction is univariant in this region and proved to be reversible in the absence of sillimanite seeds.

The runs were made in the piston-cylinder apparatus with 1-inch (2.54-cm) diameter chamber (*8*). Starting material consisted of two specimens of natural andalusite, two specimens of natural kyanite, and synthetic kyanite and andalusite. The natural minerals were analyzed with the electron microprobe.

One starting mixture consisted of

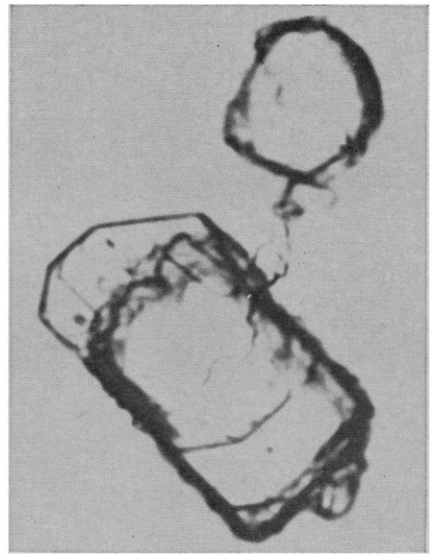

Fig. 1. Photomicrograph showing clear, geometrical end growth on kyanite seed crystal. Kyanite crystal is 20 μ wide. Other grain is quartz. Run No. 11, Table 1.

Table 1. Experimental data on the andalusite-kyanite reversible reaction. The cell constants for andalusite (Orville) are *a*, 7.802 Å; *b*, 7.887 Å; and *c*, 5.566 Å For kyanite (Tyrol) they are *a*, 7.120 Å; *b*, 7.848 Å; *c*, 5.574 Å; α, 89.98°; β, 101.18°; and γ, 105.98°. For synthetic andalusite they are *a*, 7.794 Å; *b*, 7,901 Å; and *c*, 5.561 Å. A, andalusite; K, kyanite; G, glass.

Run No.	T (°C)	P (bar)	Time (hr)	Products
Andalusite (Orville) + kyanite (Tyrol) + quartz; A = K				
1	700	5600	72	A > K; Q
2	700	6100	60	A > K; Q
3	700	6500	60	K > A; Q
4	750	6100	48	A > K; Q
5	750	6500	48	A = K; Q
6	750	7000	48	K > A; Q
7	750	7400	48	K > A; Q
8	800	6500	24	A ≫ K; Q
9	800	7000	32	A > K; Q
10	800	7400	24	K > A; Q
11	800	8100	21	K + Q
12	850	7400	5	G; A = K; Q
Andalusite (unknown) + kyanite (Litchfield) + quartz; A = K				
13	750	5600	72	A ≫ K; Q
14	750	6100	51	A > K; Q
15	750	6500	96	A = K; Q
16	750	7000	56	K > A; Q
17	750	8700	96	K + Q
18	850	7200	9	G + Q
Kyanite (synthetic, 8 + trace andalusite (Orville) + quartz				
19	750	5600	96	A + Q
Andalusite (synthetic) + trace kyanite (Tyrol) + quartz				
20	750	7400	56	A = K; Q