electron microprobe, and the laser probe thus can provide a useful supplement to major element analysis with the electron probe.

Reproducibility of spectra obtained from a compositionally homogeneous steel standard averaged ± 6.4 per cent, corresponding to a coefficient of variation of 11 per cent. Per cent transmission ratios of nickel to iron lines in a series of spectra obtained from the same standard showed a standard deviation of ± 0.051 per cent (coefficient of variation, 5.1 per cent), indicating that precision of analysis can be improved by using a variation of the internal standard principle.

Silt Dunes in a Small Flume

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Experiments on moderately well-sorted 0.4-mm silt, transported by uniform flow in a 16-foot, 6-inch wide, tilting and recirculating flume, show that, like sand but unlike very fine silt, dunes or ripples form spontaneously from an initially flat sediment bed in a sufficiently strong flow and are thereafter maintained by the flow. At low velocity or bed shear stress, the silt moves entirely as bed load, and in stronger flows, both as bed load and in suspension. Bed forms are initially low and straight-crested but become progressively higher, less regular, and more widely spaced. Equilibrium is reached only after a few hundred hours at low sediment discharges. In some conditions, small barchans are formed from an initially flat bed instead of straight ripples. Remarkably distinct internal laminations, whose causes are not entirely clear, are formed under all flow conditions that produce dunes. Geometry of the laminations in longitudinal cross section is dependent upon flow conditions.

The "Arms" of *Caryocrinites*, a Silurian Rhombiferan Cystoid

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The pinnule-bearing "arms" of the cystoid genus *Caryocrinites* directly correspond to the recumbent brachiole-bearing ambulacra of other rhombiferan cystoids. The two types of alternating arm plates represent ambulacral flooring plates, and each of the "pinnules" attached to one arm-plate set is a slightly asymmetrical, biserial brachiole.

In addition, there is a previously undescribed ambulacral crest covering the main food groove of each arm. On each side of this crest, larger vertical plates bearing horizontal prongs alternate with smaller plates without prongs in a complex repeated sequence. Short food grooves lead from the brachioles through small pores between the crest plates to the covered main food groove. When not engaged in feeding, the brachioles apparently lay in a fixed configuration against the flat vertical sides of the crest below the prongs, as their length and plate arrangement are recorded by impressions on the crest plates.

This arm-like arrangement of the ambulacra and brachioles in *Caryocrinites* was apparently a very successful crinoid-like modification for greater food-gathering capacity. With arms three to four times the calyx length, *Caryocrinites* had many more food-gathering brachioles than similar sized cystoids with the same number of recumbant ambulacra. Also, by locating the brachioles on movable arms instead of on nonmovable recumbent ambulacra, the cystoid could sweep through a much larger area in search of food particles. The pronged ambulacral crest apparently served to protect the brachioles and main food groove both during feeding and resting.

Control by Depositional Environment of Dolomitization and Porosity, Leduc Reefs, Alberta, Canada

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Control by the depositional environment of primary facies and porosity patterns and of subsequent dolomitization and secondary porosity development is evident in two Upper Devonian Leduc reefs, Alberta. The depositional environment, primary sedimentation patterns, and causes and effects of dolomitization are interpreted from the undolomitized Redwater reef and the partially dolomitized Sturgeon Lake reef.

The depositional facies pattern in the reefs is defined by (1) a concentric marginal belt of lime grainstone bounding a central area of lime mudstone to wackestone, (2) maximum sediment grain size and greatest faunal abundance and diversity as well as small amounts of skeletal framework occurring along the eastern windward margin, and (3) gypsum deposition localized in a belt about 1 mile wide along the eastern margin of Sturgeon Lake reef. Predolomitization porosity consists of interparticle pores along the reef margin, leached vugs in a belt 2–3 miles inward from the eastern edge, coinciding with a belt of islands that existed during reef formation, and burrows incompletely filled with cement in the reef center.

Dolomitization, concentrated along the eastern margin of Sturgeon Lake reef, was probably genetically related to gypsum precipitation which had a similar distribution. All preexisting porosity was destroyed during dolomitization. Porosity, subsequently created, consists of molds of fossils leached during dolomitization and fractures formed by later evaporite solution brecciation. Both secondary porosity and dolomitization were controlled by the depositional environment as it determined the original sedimentary facies pattern and the distribution of specific organisms and evaporite precipitation.

Cavansite, a New Calcium Vanadium Silicate Mineral

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Cavansite [$Ca(VO)(Si_4O_{10})\cdot 6H_2O$] was discovered at 2 Oregon localities about 300 miles apart. In 1960 it was found in a road cut near Owyhee Dam in Malheur County, and in 1963 in a quarry near Goble, Columbia County. The Owyhee occurrence is in a brown tuff in the Sucker Creek Formation of late Miocene age, and at Goble it is in basalt and breccia of the Goble Volcanic Series of Eocene age. The new mineral is found in veinlets closely associated with calcite, heulandite, and thomsonite.

Cavansite occurs in blue radiating clusters up to 25 mm in diameter and in single crystals up to 0.2 mm long. It is orthorhombic, space group *Pcmn* or $Pc2_1n$, with cell dimensions a = 9.792 ± 0.002Å, b = 13.644 ± 0.003Å, and c = 9.629 ± 0.002Å, as derived from least-squares analysis of indexed X-ray powder data. Strong lines are: 7.95(110), 100; 6.85(101), 50; 6.13(111), 35; 3.932(022), 35; 3.409(040), 70; 3.054(141), 35; 2.783(123), 35. G(meas.) = 2.25–2.36; G(X-ray) = 2.516 (assuming Z = 4). The brilliant greenish-blue crystals are biaxial negative with 2V = 51° and n_α = 1.539 (X blue, $||a$), n_β = 1.546 (Y blue, $||b$), n_γ = 1.548 (Z colorless, $||c$); dispersion strong with $r > v$. The habit is needlelike, prismatic $||c$, with {110} and {101} dominant.

A special X-ray fluorescence method was developed to determine Ca, V, and Si on 20 mg of sample; H_2O was determined separately, gravimetrically. The analyses gave: CaO, 11.5; V_2O_4, 17.1; SiO_2, 49.4; H_2O, 21.0; rem., 0.8. The blue color is characteristic of a highly

hydrated vanadyl(IV) group. The silicate framework may be a layer type (cleavage is good ||(001)), but the crystal structure has not yet been determined.

Structure of the Southern Appalachian Coal Field and Its Origin

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Initially, Lower Pennsylvanian strata were flat or even inclined toward the interior from the ancestral Appalachians and Ouachitas. The southern Appalachian coal field connected with the Illinois Basin. Subsequently, this connection was destroyed and present dips established, and Pennsylvanian rocks were involved with Appalachian structure. Alternative views of Appalachian structures are concerned with: (1) mechanics—basement and no-basement theories, (2) time of deformation—synchronous deformation and sedimentation *vs.* post-depositional deformation, and (3) formation of hydroplastic structures—near-surface slump *vs.* moderately deep bedding plane gliding.

The no-basement theory requires that location of major superficial anticlines in the plateau are controlled by buried structure or deep facies variation. The Sequatchie anticline may reflect the western limit of Conasauga shales, with décollement in Conasauga under Walden Ridge and Sand Mountain. The eastern Cumberland escarpment and related anticlines from Tennessee to Alabama may reflect a lowering of décollement level eastward from Conasauga to Rome at the western limit of Rome shales.

Stratigraphic studies show that the Sequatchie anticline formed after deposition of Pennsylvanian strata. Synchronous deformation and sedimentation may be a factor in the development of valley and ridge synclines, but this principle must not be extended with abandon into the plateau coal fields.

Décollement within Pennsylvanian rocks occurred when the rocks were hydroplastic. Bedding deformation 50–300 feet thick occurs in the oldest Pennsylvanian in Tennessee (Cumberland Plateau overthrust) and cuts upward to the west across younger strata, either forming anticlines or breaking to the surface. This overthrust is probably an example of the Hubbert-Rubey mechanism, with anomalously high pore pressures produced by osmosis and tectonic forces.

Does Paleomagnetism Provide Valid Evidence of Continental Drift?

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Interpretation of paleomagnetic data in terms of continental drift and polar wandering requires the assumption of an axial, dipolar earth magnetic field. If this assumption is correct, paleomagnetic latitude and geographic latitude at any time must coincide. Present distribution of paleomagnetic and paleoclimatic data suggests that, for the Permian, the most reliable test for coincidence can be made in North America.

The paleomagnetic equator passes through the central portion of the continent, and the geographic equator can be located by the use of diversity gradients which characteristically show a reversal in slope at the geographic equator. Diversity data for Recent pelecypods fit a present earth latitude framework but show a striking lack of fit to the Permian paleomagnetic latitude framework. Diversity data for several groups of Permian organisms show a good fit to present earth latitude but, when plotted against Permian paleomagnetic latitude, are distorted in a manner similar to that seen when Recent pelecypod diversity is plotted on this framework. For the Permian, paleomagnetic and paleoclimatic latitude frameworks show a pronounced lack of coincidence. It thus appears that the assumptions required for interpretation of paleomagnetic data as indicative of either continental drift or polar wandering do not pertain. The use of paleomagnetic data in assigning continental or polar positions seems unjustified.

Effects of Acid-Washing Procedure on Th-Pb Ages of Zircons

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The Th^{232}-Pb^{208} ages of zircons are commonly lower than the corresponding U-Pb ages, presumably due to deficiency of Pb^{208}. Experiments were made to determine whether some of this deficiency is caused by the acid-washing normally done to remove impurities. In contrast to earlier experiments, we used −102 + 286 mesh fragments from single large zircons to avoid impurities. A Ceylon zircon, which was a homogeneous gem-zircon, and a Tory Hill zircon, which is a zoned cyrtolite, were used. Both are metamict and hence should be particularly susceptible to acid-leaching. Ceylon zircon is not attacked by the normal acid-washing (40 minutes in hot HNO_3, 20 minutes in hot HCl). U, Th, and Pb concentrations and all ages agree with those from the unwashed sample split, the U-Pb ages being 2 per cent discordant and the Th^{232}-Pb^{208} ages being 10 per cent discordant. Normal acid-washing removed less than 1 per cent Pb from the Tory Hill zircon. Additional experiments were made on ground splits. Normal acid-washing of Ceylon zircon removed about 2 per cent of the Pb. Boiling Tory Hill zircon in aqua regia for 1 hour removed about 10 per cent of the U, Th, and Pb. U-Pb ages of the washed Tory Hill zircon and the aqua regia agree closely, whereas the Th^{232}-Pb^{208} age of the aqua regia wash is 70 per cent older than the Pb^{207}/Pb^{206} age of the zircon because of preferential leaching of Pb^{208}. These initial experiments suggest that normal acid-washing should not seriously affect the Th^{232}-Pb^{208} ages of zircon separates which have not been ground.

Copper-Bearing Clay Minerals in Oxidized Portions of the Disseminated Copper Deposit at Ray, Arizona

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Copper-bearing halloysite and copper montmorillonite (medmontite) are economically important minerals in oxidized portions of the copper deposit at Ray, Arizona. Kennecott Copper Corporation is currently developing a modified vat leach process to recover copper from this material.

Copper halloysite occurs in the deposit as veinlets and coating of fracture surfaces. It commonly has colloform structure and may be intergrown with chrysocolla. Copper content of the halloysite ranges from nil to 17 per cent and its color ranges from white to deep blue green. Copper is readily leached from the halloysite by dilute sulfuric acid solutions. Good extraction of the copper is obtained, but consumption of acid is high because considerable aluminum is also dissolved from the clay.

Copper montmorillonite (medmontite) is disseminated throughout the matrix of the host rocks of the deposit. It is particularly abundant in mineralized and altered dacite welded tuff where it formed as a devitrification product of the volcanic glass. In this rock the copper montmorillonite forms alteration haloes surrounding phenocrysts and rock-fragment inclusions. Concentrates of copper montmorillonite contained as much as 3.2 per cent copper. This mineral caused problems in leaching tests because its copper content was not extracted by the dilute sulfuric acid leach solution.