Colorado. Although the other vertebrate-bearing deposits, in Wyoming, South Dakota and Montana, appear to be of similar age, they may well be slightly earlier or later within the Middle Ordovician. It is therefore possible that two or three distinct vertebrate faunas may be represented. The range of these vertebrates into earlier or later times is unknown, and they are therefore not reliable as index fossils for the Middle Ordovician.

Denison describes studies of the sedimentation of the Harding Formation in Wyoming which show that the lowest part of this marine sandstone, which does not contain vertebrate fragments, was formed at least a few miles from the source of the sediments. The vertebrates are found in the coarser upper parts of the sandstone, in which there are occasional large quartz grains and, near the top, the remains of marine invertebrates. The large quartz grains are interpreted as wind blown sand, indicating that deposition was then taking place closer to the shore. The Harding Formation is followed by the thick Bighorn Dolomite, which contains a marine invertebrate fauna. Denison considers that these studies provide further support for his view that the earliest vertebrates lived in the sea.

Denison also describes a partially articulated head-shield of *Eriptychius*. Associated with this were several large elements of globular calcified cartilage—the first evidence of a calcified endoskeleton in the Heterostraci. Denison could find no trace of cell spaces or of canaliculi in the aspidine of the dermal bones and scales of *Eriptychius*. He refers *Pycnaspis* from Wyoming to the genus *Astraspis*, which is therefore the only other known genus of Ordovician vertebrate. Discussing the histology of the dermal bones and scales of *Astraspis*, he concludes that the tubercles consist of durodentine and orthodentine and that the tissues of the middle layer may be a variety of trabecular dentine, rather than aspidine.

In a second paper (*Fieldiana: Geology*, 17, 353; 1968), Denison describes *Uranolophus*, a new genus of lungfish from the Beartooth Butte Formation of Wyoming and from the Water Canyon Formation of Utah and Idaho. These formations have been correlated with the Early or perhaps Middle Siegenian (Early Devonian) of Western Europe which would imply that *Uranolophus* is the earliest lungfish known, slightly pre-dating *Dipnorhynchus* of the Late Siegenian of Germany and Australia. *Dipnorhynchus* occurs in undoubtedly marine rocks, but the environment of *Uranolophus* is less certain. There are no invertebrates definitely associated with marine conditions and the Wyoming specimens were deposited in channels cut into the underlying limestones. These channels, however, do not necessarily represent freshwater stream courses, for much of the Beartooth Butte vertebrate fauna also occurs in the Water Canyon Formation, at least part of which is a marine deposit. Denison provisionally concludes that deposition took place in extremely varied conditions, some of which may have been on the margins of the sea and others in freshwater streams and pools.

The most important morphological features of *Uranolophus* include its very short nasal region, the long palate and the relatively large dorsal fin. Instead of tooth plates on the palate and lower jaw, there are "tooth ridges" composed of dentine. Denison believes that this is unlikely to be a secondary condition, and suggests that tooth plates may have evolved in only

one line of lungfish, rather than being a primitive characteristic of the group.

Unequal Heat Flows

from a Geophysics Correspondent

ONE of the most important and unexpected results to be derived from terrestrial heat flow measurement is the apparent equality of heat flow averages over continental and oceanic areas. This discovery is unexpected because geochemical indications of higher radioactive content in continental material imply that the rate of heat flow should be greater over land than through the ocean floor.

One reason why the observed equality may be more apparent than real has now been advanced by Crain (*Earth and Planet. Sci. Letters*, 4, 69; 1968), who suggests that equilibrium heat flow conditions may not yet have been re-established over continental areas since the last glaciation. During a period of glaciation the temperature at the interface between land and ice is probably between -2°C and -8°C . After the withdrawal of the ice and the consequent increase in temperature, the distribution of heat flow with depth will not, theoretically, return to its pre-glacial equilibrium for tens of thousands of years. The effect of a deglaciation 10,000 years ago will thus have been to produce an apparent increase of heat flow to a depth of about 2,000 metres. Measurements less than 2,000 metres below the surface of the Earth should therefore indicate artificially low rates of heat flow.

An analysis of heat flow data from the Appalachian region of North America indicates that there is indeed a tendency towards higher heat flows at greater depths within a borehole. The chances of such a correlation arising by chance are less than one in ten thousand. If the raw heat flow data are corrected to take into account a 10°C rise in temperature at the time of the Wisconsin deglaciation, however, the correlation disappears. Similarly, an apparent difference in rates of heat flow between two widely separated areas of the Ukrainian Shield disappears if the difference in borehole depths is taken into account by Crain's hypothesis.

It may be held that Crain's argument can only be valid in regions which experienced the Wisconsin glaciation. There is some evidence, however (Broecker *et al.*, *Am. J. Sci.*, 258, 429; 1960), that the climatic change which caused the most recent glaciation may have been a world-wide phenomenon, so that the temperature increase might well have been universal, thereby increasing all continental heat flow values in accordance with geochemical expectations. Evidence for this must come from further analyses but, as Crain points out, "the apparent equality of the oceanic and continental heat flow values should be seriously questioned, before it is used as a base for broader geophysical deductions".

Superplasticity

from our Materials Science Correspondent

METALS and alloys are widely used as industrial materials largely because, from the ingot, they can easily be formed into diverse shapes. A piece of metal, when stretched, can only stand a limited extension