Dinosaur-footprints and polar wandering

BY

NATASCHA HEINTZ

Abstract

The discovery of *Iguanodon*-footprints in Vestspitsbergen at c. 78° N. lat. is mentioned. The presence of large terrestrical reptilies in Cretaceous times at this high latitude is discussed in relation to a possible dark season in this region at that time. The possibilities of polar wandering, giving Svalbard another position in relation to the North Pole is considered, and what this would mean for the reptilies living at Svalbard. Lastly it is pointed out that find of *Iguanodon*-footprints in Svalbard brings up a whole series of geological and biological problems.

Altogether 13 footprints were found at Festningen, a point near the mouth of Isfjorden in Vestspitsbergen. However, some of them were rather poorly preserved. The footprints were of different size, this being an indication that that they had been made by several animals. This assumption was further underlined by the fact that one could follow more than one direction of tracks (Fig. 1). The best preserved footprints were distinct and made it possible with a high degree of certainty to determine these footprints to have been made by representatives of the genus *Iquanodon* (LAPPARANT, 1962), presumably *I. bernissartensis*.

The footprints from Festningen do not provide us with any important new information concerning the structure of *Iquanodon*'s feet. The fact is that the skeleton of *Iquanodon* is very well known. In 1878 an outstanding find was made in Bernissart near Mons in Belgium, where in a coalmine not less than 23 more or less complete skeletons of *Iquanodon* were found. The find has been described in great detail in many papers, first of all by L. DOLLO, and quite recently a comprehensive book on the Bernissart *Iquanodons* has been published by E. CASIER (1960). The great significance of the dinosaur-footprints found at Svalbard lies in the fact that this is the first time any traces of terrestrical reptiles have been found within the area today called Svalbard or any other places lying so far north.

The great expansion of the area of distribution of *Iquanodon* brings up several interesting problems of more general character. The present author thus thinks it could perhaps be of some interest to examine some of these problems a little more closely.

According to Fig. 2, based on information from many papers (CASIER, 1960; E. COLBERT, 1962; A. F. DE LAPPARANT, 1962; W. E. SWINTON, 1934; H. & G. TERMIER, 1960), it can be seen that the genus *Iquanodon* in the Lower Cretaceous

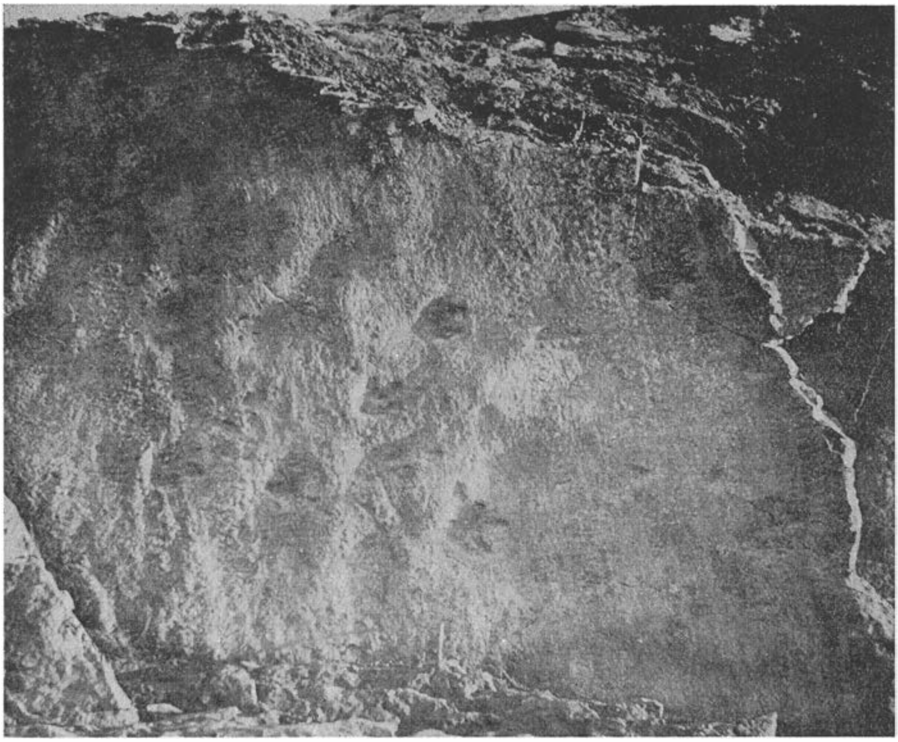

Fig. 1. *The sandstone-layers at Festningen, Vestspitsbergen, with the Iguanodon-footprints, photographed in the slanting rays of the midnight sun* (*After* A. F. DE LAPPARENT).

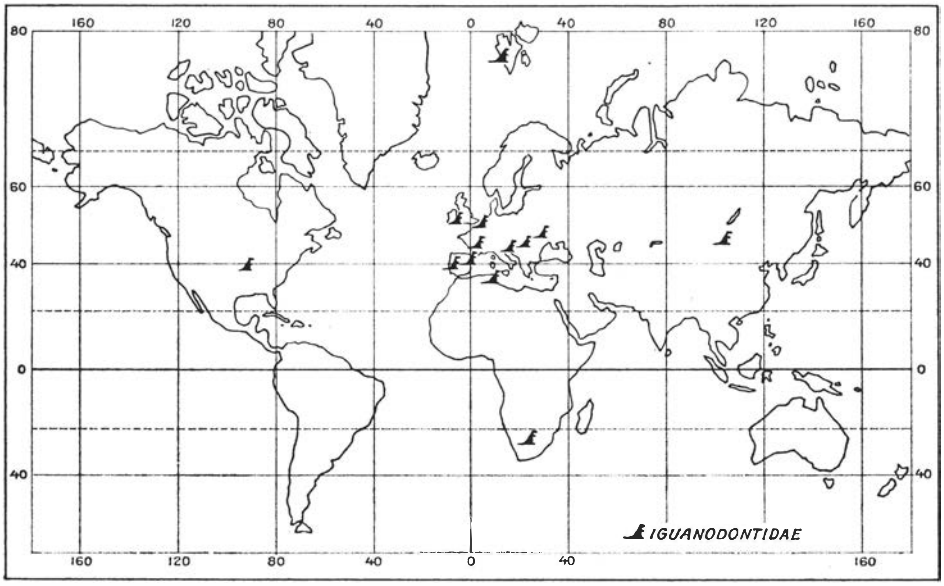

Fig. 2. *The distribution of Iguanodontidae. Partly after* E. CASIER.

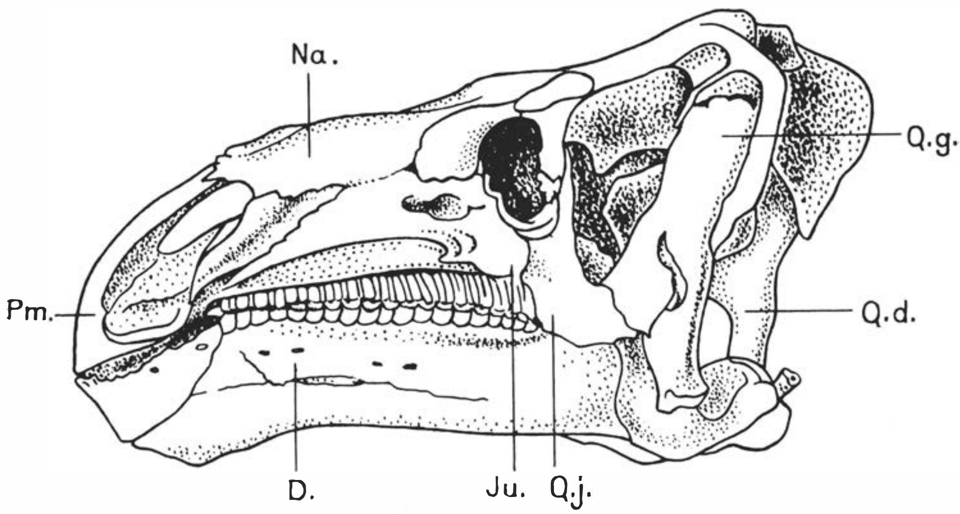

Fig. 3. *The skull of Iguanodon bernissartensis. Partly after* E. Casier *and* K. Zittel. *D = dentale; Ju = jugale; Na = nasale; Q.d. = quadratum (right); Q.g. = quadratum (left); Q.j. = quadratum–jugale; T. = teeth.*

was found over very large parts of the world. Fossils or footprints of this genus are known from South England, Central Europe, North and South Africa, Central Asia and the southern parts of North America, and now also in Spitsbergen.

The genus *Iquanodon* belongs to Ornitischia and their teeth show that they were typical herbivorous animals (Fig. 3). The teeth were gathered in several rows that were placed in the longitudinal direction of the jaws. The surface of the teeth was rough and the animal was thus well suited for living on a plant diet (CASIER, 1960; ZITTEL, 1890). The shape of the jaw was specially adapted for grinding vegetable food, as the joint between the lower and upper jaws was situated lower than the surface of the teeth, allowing the teeth of the lower and upper jaws to get in contact with one another all at once when the animal started chewing. This low joint is due to the quadratum being greatly extended (Fig. 3).

The presence of *Iguanodon* in Svalbard shows that in Lower Cretaceous there must have been a fairly abundant vegetation in these northern regions, supplying these large animals with food. As known, *Iguanodon* belongs to the larger dinosaurs and even if the reptiles do not have such a high metabolism as mammals, an animal being 10 to 12 m long and 3 to 5 m high needs quite large quantities of food (Fig. 4).

Palaeogeographical maps shown that so far one has not found any terrestrical animals that have been dependent upon a landbridge between the Svalbard area and the Eurasian continent (BRINKMANN, 1948; TERMIER, 1960). The presence of dinosaurs at Svalbard in Lower Cretaceous shows, however, that a landbridge must have existed at that time.

The presence of a landbridge between Svalbard and the Eurasian continent in late Mesozoic is a rather interesting fact. However, there is another problem, that in my opinion is worth discussing a little further. It can be formulated briefly as follows:

"What did large terrestrical reptiles do, e.g. *Iguanodons*, during the dark season of the year?"

No doubt this problem is of considerable interest and it involves a whole series of more general geological and palaeontological considerations. Presenting the question in the way it has been done above, we have assumed that the Svalbard region in the beginning of the Cretaceous period had about the same position in relation to the axis of rotation, viz. the geographical North Pole as it has today. Theoretically it is possible that the axis of rotation had another angle to the ecliptic and some authors favour that view. However, most others find that geophysical and astronomical evidences make this rather unlikely (BERNARD, 1963; BROUWER, 1953).

On the contrary, studies of recent earth magnetism and palaeomagnetism has revealed that the magnetic poles constantly are shifting (RUNCORN, 1955). Indications can be found that it is not only the magnetic poles that are being moved, but that the continents during the geological past have changed their positions in relation to their present site (DU TOIT, 1937; OFTEDAHL, 1962, oral communication). RUNCORN (1960) says that the palaeomagnetic measurements indicate that: "After Triassic times, a relative motion of North America and Europe took place. It is not by any means easy to be specific about the value of this displacement, but estimates range from a value of about 24° to 45°".

The result of a displacement as mentioned above, would be that regions that today lie well north of the Arctic Circle, in earlier periods would lie south of the Arctic Circle and would thus not have been affected by the dark season of the year.

In present days, in Central Spitsbergen the sun passes below the horizon at the end of October and is not back again until the last days of February, while from the last days of April and until the end of August the sun never gets below the horizon. This means that during 4 months the sun never sets, while during another 4 months it does not get above the horizon.

For vegetation this is of vital importance. Even if the climate had been warm enough during the dark period, so that growth could have taken place, a rest-period of about 5 months must have come into being. The total lack of light makes it absolutely impossible for the photosynthetic processes of the plants to go on. There is also another side to this problem. For the deciduous trees a warm, dark period is no severe problem. They drop their leaves in the autumn and have a period with a minimum of breathing during the dark period. The problem seems, however, to be quite different for the conifers. A warm or even mild climate makes them go on breathing on a high rate, while the darkness on the other side, puts a full stop to the photosynthetic processes. On the contrary, during a cold and dark period the breathing also by the conifers will be restricted to a minimum.

Thus, if Svalbard in the beginning of the Cretaceous period was situated north of the Arctic Circle, *Iguanodon* would be faced with the problem, for a shortre or longer time of the year — to manage through a dark season.

As will be known, reptiles are ectothermic or "cold-blooded" animals and

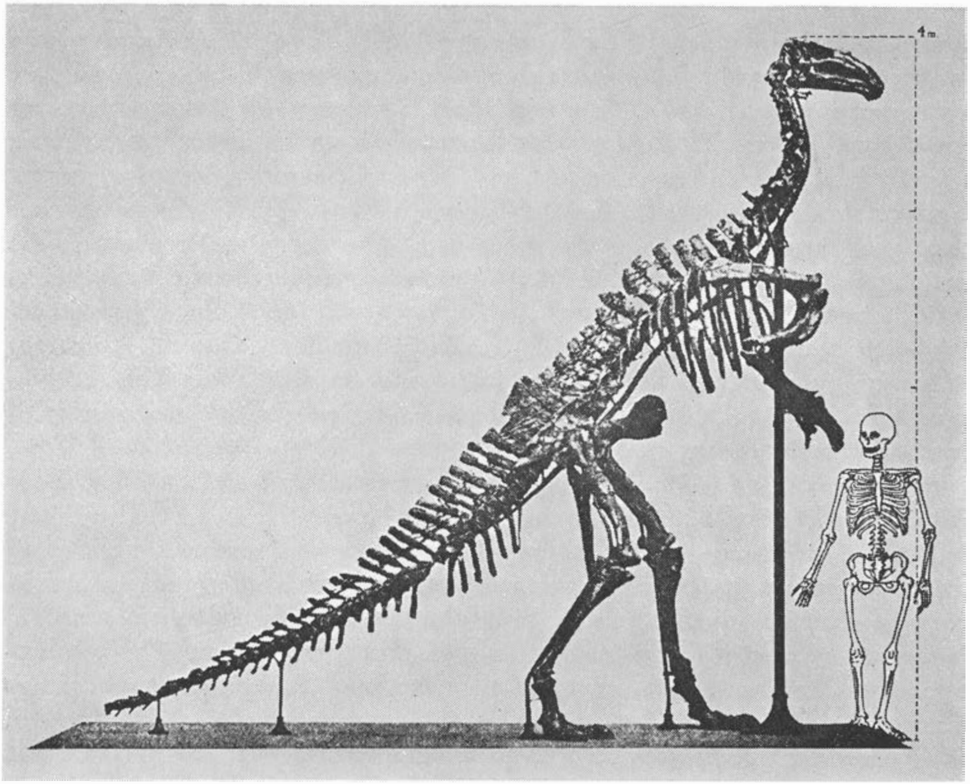

Fig. 4. *The skeleton of. I. bernissartensis from Belgium compared with the skeleton of man. The height of the animals is 4 m. After* E. CASIER.

their body-temperature is to a great extent controlled by the temperature of the environments in which they live. Studies of recent reptiles have shown that they are active only within a fairly limited temperature interval. Thus, if the temperature rises above +45 °C, most reptiles would die within reasonably short time. On the contrary, when the temperature drops below 0 °C, they fall in a lethargic sleep, but already at about +20° to +10 °C many reptiles are rather sluggish and inactive. One can easily observe how reptiles early in the morning lie flat along the ground, to get as much warmth from the sun as possible. As the temperature rises during the day, they raise the front part of their body and turn it towards the sun — so that the part of the body that is directly hit by the sun, is as small as possible.

Even though the climate in early Cretaceous days was obviously warmer than it is today, it seems reasonable to assume that the temperature during the dark season must have dropped. The direct irradiation of the sun is, however, of considerable importance for the temperature conditions.

It is therefore not unreasonable to assume that during the dark season the reptiles must have been lying in some sort of dormant. The conditions in Norway in our days show that reptiles can be lying dormant during the winters, as f.ex. all the Norwegian reptilies do. Normally they either crouch together in small holes or bury in plantremains etc. It is, however, difficult to think of large animals as *Iguanodons* being 10 to 12 m long, finding caves or holes large enough for them to winter in. The same also applies if they should be burying in the ground or in plant-remains. COLBERT (1963) says that when it comes to recent amphibians and reptiles it seems that there are no special difficulties for small animals to manage in temperate or even fairly cool climate, if only the summer temperature is high enough. The small forms hibernate during the winter. For large ectothermal animals on the other hand, the winter temperature is the limiting factor of their distribution. We must presume that large ectothermal animals have difficulties in finding suitable places where they can hibernate. On this base COLBERT concludes that: "There can be little doubt as to the limitations of these huge reptilies to tropical and subtropical climates..." and he also says that: "The strugglers that venture beyond in to higher latitudes are generally of small or very moderate size...".

However, if Svalbard in the beginning of Cretaceous where situated at about the same place in relation to the geographical North Pole, we could think of solving the problems of *Iguanodon* living in these northern regions, by regarding them as "reptiles of passage". During the summer-season the *Iguanodon* would be present in the Svalbard region while during the dark season they would move southwards to areas lying south of the Arctic Circle. This assumption seems, however, rather doubtful if one takes into consideration the enormous distances *Iguanodon* in this case would have to cover twice a year, even though, as COLBERT (1962) points out: "Large vertebrates like the dinosaurs are and always have been very mobile organisms; they are inclined to wander back and forth, to and from water, to and from feeding grounds." The distance from the Isfjorden region in Central Vestspitsbergen to the Arctic Circle is today about 12° lat., i.e. 1300 km. If we presume that the *Iguanodons* as an average could cover about 20-25 km per day, they would need more than 2 months on the distance from Svalbard to the Arctic Circle. This means that they as an average would spend about 4 months wandering from the northern regions southwards and return again. Even though we may have been a little too careful in estimating the time needed, the fact cannot be overseen, that the dinosaurs would use a comparatively large part of the year to go forth and back from the Arctic regions. In this connection it must be mentioned that it is rather unlikely that it has been possible for *Iguanodon* to lay their eggs in these northern regions. Even if the eggs were laid immediately upon their arrival at Svalbard, a fair amount of time would be needed before the eggs were hatched and the young would hardly get sufficiant time to grow so much, that they either could manage to hibernate through the winter, or to travel southwards in the autumn. However, the more fundamental question is, why should the large *Iguanodons* travel northwards during the summer?

As we know today, many birds cover large distances each spring going northwards for the summer and returning to warmer places in the autumn. The reason for this is that the birds in the Arctic and Sub-Arctic regions in summertime find good breeding-places and great amounts of food.

A warm period with light all day and night through could certainly favour a luxurious vegetation. The find of plant-fossils at Svalbard so far neither support nor oppose this assumption. One can also think that in more southerly regions the summers were very hot and dry, making it difficult for large reptiles to find sufficient food. Of course, it may have happened that *Iguanodon* each year covered large distances in search for food, but the author finds it rather unlikelv that *Iguanodon* is found in Svalbard in Lower Cretaceous, because they come there only during the summer.

Presuming that *Iguanodon* could stay the whole year in Svalbard, the question concerning reproduction again comes into focus. The recent reptiles either lay eggs or give birth to young ones. In the last case the eggs are kept within the body of the female until the eggs are ready for hatching. Today such a solution is found i.a. in reptiles that live far north f.ex. in Norway, it applies to the Norwegian viper. If in our case the copulation took place in the autumn before the dark season and the female carried the eggs until the sun again rose, the young ones being born early in the spring, would have the possibilities of getting the most out of the light time of the year. In all other cases a shorter or longer part of the light period had gone before the young could start living by themselves and get on growing in order to manage the dark season.

If we now try to summarize some of the different aspects that have been discussed on the previous pages, two main points seem to come forward.

Assuming that the geographical North Pole in the beginning of the Cretaceous period was situated about the same place as it is today, the continents that lay north of the Arctic Circle would have a shorter or longer period of the year, when it was totally dark, and correspondingly a period when the sun never passed below the horizon.

If the Svalbard archipelago at that time was situated at about the same place as today in relation to the geographical North Pole, all animals and all plants that were found there must have been adapted to a four months long dark season.

When it comes to the ectothermal, terrestrical animals, we could think that they either hibernate in holes and caves or bury in the ground. This would work well with small animals, while it would be much more difficult for the larger ones. The presence of a landbridge connecting Svalbard with the Eurasian continent would, however, make it possible for the large terrestrical animals to travel southwards during the dark season and in this way solve their problems.

There are, however, today several indications that make it not unreasonable to assume that during the geological history the continents have moved both in connection to each other and in relation to their present position (BERNARD, 1963; NAIRN & THORLEY, 1961). This means that in earlier geological periods they would have had another position in relation to the geographical North Pole than they have today. Palaeomagnetic investigations based on rocks from the Cretaceous show that the magnetic North Pole at that time presumably did not lie far from the Siberian coast (RUNCORN, 1956, fig. 9). This means that Svalbard at that time must have been situated a good bit further south than it is today, and the dark season must have been very short or lacking totally. If this explanation is accepted, the presence of *Iguanodon* in Svalbard is no problem. A mild climate and no dark season or only a short one would hardly in any severe way effect either the flora or the fauna.

The find of *Iguanodon*-footprints in Svalbard show that either we have to figure on a fairy large shifting of the Svalbard area from Cretaceous up to present time or *Iguanodon* must have had some special adaptions to manage a long, dark winter, that we do not know today. The same also applies to the flora, that particularly seems to have had difficulties in managing through a mild, dark season.

As indicated earlier in this paper, the find of *Iguanodon* in Svalbard brings up many very interesting problems, both of biological and geological character. We can, however, by no means say that we have reached the solution of any of these problems. The intention of this short paper is, however, first of all to point at the fact that even if the climatic conditions in earlier periods of the earth history have been different from what they are today, there must have been areas somewhere with seasons of darkness and seasons of light, if the rotation axis of the earth has not changed its position in relation to the ecliptic, which is hardly in question.

Acknowledgement

I would very much like to express my gratitude to my colleagues and friends at Norsk Polarinstitutt and Paleontological Museum in Oslo for valuable discussions and interest shown in the present work. However, I owe special thanks to my father, professor dr. A. HEINTZ and my husband, geologist T. SIGGERUD for their never failing interest and encouragement.

"NATO Advanced Study Institute" is rendered thanks for financial aid to take part in a symposium on palaeoclimatology in Newcastle, England, in January 1963.

I also wish to thank Mr. W. B. HARLAND for his comments and for correcting my English.

Literature

BARGHOORN, E. S., 1953: Evidence of climatic change in the geologic record of plant life. In SHAPLEY, H.: *Climatic change*. Harvard University Press, Cambridge, USA.

BERNARD, E. A., 1963: The laws of physical palaeoclimatology and the logical significance of palaeoclimatic data. Papers from: *Symposium on Palaeoclimatology*. (MS). Newcastle, Jan. 1963.

BRINKMANN, R., 1948: In EMANUEL KAYSER: *Abriss der Geologie*. **II.** Historische Geologie. F. Enke Verlag. Stuttgart.

BROUWER, D., 1953: The polar motion and changes in the earth's orbit. In SHAPLEY, H.: *Climatic change*.

CASIER, E., 1960: *Les Iguanodons de Bernissart*. Inst. R. des Scienc. Nat. de Belgique. Bruxelles.

COLBERT, E. H., 1945: *The dinosaur book*. The Am. Mus. of Nat. His. New York.

— 1953: The record of climatic changes as revealed by vertebrate paleontology. In SHAPLEY, H.: *Climatic change*.

— 1962: *Dinosaurs. Their discovery and their world*. Hutchison of London. London.

— 1963: Climatic zonation and terrestrical faunas. Paper from: *Symposium on Palaeoclimatology*. (MS). Newcastle, Jan. 1963.

COX, A. and R. R. DOELL, 1960: Review of paleomagnetism. *Bull. Geol. Soc. of America.* **71**: 645-768.
DU TOIT, A. L., 1937: *Our wandering continents.* Oliver and Boyd. London.
KRÄUSEL, R., 1961: Palaeobotanical evidence of climate. In NAIRN, A. E. M.: *Descriptive palaeoclimatology.* Interscience publishers Inc. New York and London.
LAPPARENT, A. F. DE et R. LAVOCAT, 1955: Dinosauriens. In *Traite de paleontologie.* **V.** Ed. J. PIVETEAU. Masson et Cie. Paris.
LAPPARENT, A. F. DE, 1962: Footprints of Dinosaur in the Lower Cretaceous of Vestspitsbergen-Svalbard. *Norsk Polarinstitutt Årbok 1960.* Oslo.
NAIRN, A. E. M., 1961: The scope of palaeoclimatology. In NAIRN, A. E. M.: *Descriptive palaeoclimatology.*
— and N. THORLEY, 1961: The application of geophysics to palaeoclimatology. In NAIN, A. E. M.: *Descriptive palaeoclimatology.*
OPDYKE, N. D. and S. K. RUNCORN, 1959: Paleomagnetism and ancient wind directions. *Endeavour.* **XVIII,** (69). London.
ORVIN, A. K., 1940: Outline of the geological history of Spitsbergen. *Skr. om Svalb. og Ishavet.* Nr. 78. Oslo.
ROMER, A. S., 1961: Palaeozoological evidence of climate. (1) Vertebrates. In NAIRN, A. E. M.: *Descriptive palaeoclimatology.*
RUNCORN, S. K., 1955: The permanent magnetization of rocks. *Endeavour.* **XVI,** (55). London.
— 1956: Paleomagnetic survey in Arizona and Utah. Preliminary results. *Bull. Geol. Soc. Amer.* **67:** 301. Baltimore.
— 1960: Rock magnetism. *Science.* Apr. 17, 1959. 1002-12.
SCHULMAN, E., 1953: Tree-ring evidence for climatic changes. In SHAPLEY, H.: *Climatic change.*
SWINTON, W. E., 1934: *The dinosaurs.* Thomas Murby & Co. London.
TERMIER, H. et G., 1960: *Atlas de paleogeographie.* Masson et Cie. Paris.
TOMKIEFF, S. I., 1963: Palaeomagnetic studies in the U.S.S.R. *Nature.* 197.
ZITTEL, K. A., 1887-1890: *Palæozoologie.* Vertebrata. III. München und Leipzig.