

ART. XXX.—*An examination of the arguments given by NEUMAYR for the existence of climatic zones in Jurassic times;* by ARNOLD E. ORTMANN.

IN a recent publication (*Principles of marine Zoogeography*)\* the present writer incidentally indicated the reasons why Neumayr's theory of climatic zones in the Jurassic period cannot be accepted as correct. It may be allowed to enter into details in the present article, since my views differ so widely from these of Neumayr, and especially since many prominent geologists have adopted his views more or less completely.

It is very important to examine closely the arguments of Neumayr himself and his defense against the objections made by other scientists. Although the arguments are collected in a special paper (1883), the detailed palæontological investigations and the conclusions derived from particular cases are scattered through a large number of publications, and therefore it would be perhaps desirable to give here a list of the papers referred to.

- 1871. Jurastudien, 5. Der penninische Klippenzug.—Jahrb. K. K. Geol. Reichsanstalt, vol. xxi, p. 503–526.
- 1876. Die Ornatenthone von Tschulkowo und die Stellung des russischen Jura.—Benecke's geogn. palæont. Beiträge II.
- 1877. Bemerkungen über den russischen Jura.—Neues Jahrb. Min. Geol. Pal. 1877.
- 1883. Ueber Klimatische Zonen während der Jura—und Kreideperiode.—Denkschr. K. K. Akad. Wiss. Wien., vol. xlvii.
- 1885. Die geographische Verbreitung der Juraformation.—ibid., vol. l.
- 1887. Ueber die Beziehungen zwischen der russischen und west-europäischen Juraformation.—Neues Jahrb. etc. 1887, 1. †
- 1890. Kritische Bemerkungen ueber die Verbreitung des Jura.—ibid. 1890, 1.
- 1890. Erdgeschichte, vol. II.

The supposition, that in the Jurassic time climatic zones were developed on the earth, was first made by Marcou, but it attracted no attention until Neumayr attempted to prove this theory by palæontological and geological evidence. The demonstration given by him proceeds in the following manner.

He investigated the different faunas, especially of the middle and upper Jura in the different localities of Europe, and

\* Grundzüge der marinen Tiergeographie, Jena, 1896, p. 62. 63.

† This is a reply to a paper under the same heading published by Nikitin in 1886 in the same periodical.

discovered, mostly in the groups of cephalopods, certain peculiarities of distribution, consisting chiefly in the presence of certain genera (*Phylloceras*, *Lytoceras*, *Simoceras*) in the southern European deposits, but wanting or represented only rarely in the deposits of the other parts of Europe. The northern boundary of this southern province, the Mediterranean, follows, generally speaking, the course of the Alps and Carpathian mountains. In the other parts of Europe, the Jurassic deposits of England, France, Germany, Poland, show further differences from those of Russia; the former, the Middle-European province, possesses peculiar cephalopod-genera, such as *Oppelia*, *Aspidoceras*, while in the latter, the Russian province, these are nearly wanting and other animals are here abundantly developed, such as species of the group of *Belemnites excentricus*, and of the Lamellibranchiate-genus *Aucella*.

Neumayr resolved to investigate the causes of these apparent faunistic differences of strata formed at the same times, and his considerations are the following. Such differences may be due either to topographical causes, such as separation of the relative basins by land, or as differences of facies or depth of the sea; or they may be due to climatic causes. Believing further, to have demonstrated the impossibility of the action of such topographical causes as named, he concludes that the only remaining way for explaining the existing differences is by supposing that climatic differences of the sea are responsible for them. This supposition is strengthened, according to him, by the situation of these "provinces," being limited each to a circumpolar zone around the earth.

An investigation of Neumayr's views is therefore divided conveniently into three separate parts: 1. An examination, whether differences of the faunas are really present; 2. An examination, whether the proofs given for the impossibility of the action of topographical causes are sufficient; 3. An examination, whether the circumpolar zones are confirmed in a satisfactory manner.

But, before this, we have to decide a preliminary question: whether the groups of animals investigated by Neumayr give us a guarantee that their distribution is able at all to indicate climatic differences. Further, in conclusion, we will demonstrate that many additional objections can be made to the climatic zones of the Jura, even if their existence is supposed to be granted.

I. The group of animals, the fossil remains of which are most especially studied by Neumayr, and from the distribution of which his arguments are taken, is that of the Ammonites. This group is extinct in the recent seas; the now living

*Nautilus* only is in some way related to it, but we have reason to suppose that the habits of the *Ammonites* were generally the same as in *Nautilus*. From the latter animal recently J. Walther\* has inferred a peculiar fact in regard to the *Ammonites*, namely that the living animals were restricted in their distribution to narrow limits within the littoral district of the sea, but that after the death of the animal the empty shell, provided with air chambers, rose to the surface of the sea and was transported by wind and currents. Thus the shells were dispersed all over the earth and were deposited as fossils in parts where the living animal did not exist. According to this peculiarity, he says that the *Ammonites* are true "characteristic fossils," as they are to be found in all the deposits of the same time on the whole earth.

This supposition is without any proper foundation, even in case the *Ammonites* possessed the same habits as *Nautilus*. The living *Nautilus* is *not restricted* to a limited range, as supposed by Walther (l. c. p. 513.) It is true, the living animal has been found up to the present time only in a few localities, but even these localities, scattered in the Pacific Ocean,† indicate a more extensive distribution within this area, and I may add, that I have ample reason for believing that the living *Nautilus* is also an inhabitant of the eastern coast of Africa.‡ This distribution would not be strange; on the contrary, the range of *Nautilus* would be in accordance with that of the other animals belonging to the littoral Indo-Pacific fauna. Further, the empty shells of *Nautilus* occur only in the Indo-Pacific Ocean, the statement made by Walther (l. c. p. 513), that their distribution is an universal one, being incorrect, and thus the distribution of the shells does not occupy a wider area than that of the living animal. On the

\* Einleitung in die Geologie als historische Wissenschaft II. Lebensweise der Meerestiere 1893, p. 509ff.

† For instance: Amboina, New Guinea, New Hebrides, New Caledonia, Fiji Islands.

‡ During my stay on the east coast of Africa I collected positive information about the existence of living *Nautilus* near the harbor of Dar-es-Salaam. I was shown two very fresh specimens of the shell, and the owner of one of them told me, without being asked, that he found the shell on the beach after a high tide with an animal inside, which he had much difficulty in extracting. Hearing from me that the animal was a very valuable one, he was sorry not to have preserved it, and farther on, he spent his leisure time in search for another specimen, and that without my knowledge, apparently intending to sell it to me if possible. He was not successful. I trust wholly in the correctness of his information, as I received others from him regarding zoölogical objects which proved to be trustworthy. Later on I found out that the animal is generally known among the negro fishermen living on the beach. According to their own words, it lives "kisiwani," ("among the islands," situated off the coast), and in "maji mingi" ("deep water," for the coast-negro 10 to 20 fathoms are "deep water"). The animal is not rarely captured by them, but it is always thrown away as of no use for them.

other hand, if the alleged transportation of the empty shells of the Ammonites over the seas should be correct, we ought to observe actually a world-wide distribution of the fossil Ammonite-species, but this is not the case. Some species indeed are found in the same zone all over the European Jura, and some of them are found even in extra-European localities, but this fact can never be a proof of the universal distribution of the Ammonites in general. On the contrary, most of the species are found only in limited localities and almost every locality has its peculiar species. Whoever is occupied in determining the different species of Ammonites and is familiar with the systematic diversity of this group, ought to know the local restriction of most of the species.\*

Neumayr, on the contrary, is inclined to regard the Ammonites as animals swimming on the surface of the sea, as belonging to the pelagic fauna (see *Erdgeschichte*, 1890, p. 270). It seems that he was not aware that this supposition is very dangerous to his theory. I do not want to deny that the possibility must be granted, that perhaps some species or genera of Ammonites belonged to the pelagic fauna, as well as that some of them lived perhaps in abyssal depths of the sea; but by the actual distribution of these fossils I am convinced that by far the greatest number of Ammonites lived as benthonic animals in the moderate depth of the littoral, and in this point I agree with Walther (l. c. p. 515). But further I am convinced that they lived even in these places where now their shells are found in the fossil state. It may be that the empty shells could be transported in the manner mentioned, but such a transportation could not take place over large tracts of the seas, and could not be the normal condition of things; otherwise the actual distribution of the species of Ammonites would be entirely different.

From the foregoing considerations we have to conclude that the Ammonites can furnish us with sure evidence for the existence of faunistic differences, as Neumayr has indicated.

I have still to make some remarks on the Reef-corals alluded to now and then by Neumayr. Contrary to the Ammonites, he tries to abate the value of the proof given by the Reef-corals in regard to the former climatic conditions. Generally we are wont to conclude from the recent exclusive distribution of the Reef-corals in the tropical seas, that the fossil Reef-corals also lived in seas of a tropical climate. Neumayr, however, urges on several occasions that we have no sufficient reason for so doing, since Reef-corals may have

\* Already Tornquist (*Fragmente einer Oxford fauna von Mtaru.—Jahrb. Hamb. Wiss. Anst.* X. 2, 1893, p. 24) calls Walther's hypothesis an "incomprehensible" one.

lived in former times in cooler water. In this point, I believe, Neumayr's view is incorrect. We are justified in supposing that animals living in cooler water are to be traced back to such ones living in the tropics in former times, that is to say, the adaptation to a cooler climate is a more recent acquisition. But it is very improbable that animals living originally in cooler water migrated back into the tropics, because they would find there a most dangerous concurrence in the struggle of life by the well adapted tropical fauna, while they themselves were not so well fitted for the tropical conditions. Therefore the stenotherm Reef-corals living nowadays exclusively in the tropics and showing no traces of existence in the cooler seas, were most probably stenotherm tropical animals also in former times. If in any groups of animals, we have surely in the Reef-corals sufficient reason for arguing from the recent conditions to the former ones; especially is this the case in the Mesozoic corals, since these are the direct ancestors of the Tertiary and recent corals.

II. The palæontological foundations of Neumayr's theory, taken principally from the Ammonites, are the following: The Mediterranean province is characterized by the most general and frequent presence of the genera *Phylloceras*, *Lytoceras*, and *Simoceras* in all the cephalopod-beds, and a very peculiar deposit of this province are the Aptychus-beds. Both the genera just mentioned and the Aptychus-beds are either very rare or wholly wanting in the Middle-European province. The latter, however, shows often a local development of Sponge-fields and Coral-reefs, connected with the abundance of certain gasteropods, such as *Nerinea*. On the other hand the genera *Oppelia*, *Peltoceras*, *Aspidoceras*, very frequent in middle Europe, are very rare in the Russian province and the same is the case in the Reef-corals. In the latter province again the genus *Cardioceras*, the group of *Belemnites excentricus*, and certain bivalves, such as *Aucella* (Aucella-beds), prevail.

These differences cannot be overlooked. Nikitin, indeed, attempted to reduce these differences for the Russian Jura, and in some instances, for example as regards the genus *Cardioceras*, he is right (l. c. 1886, p. 232); but his statement, that there prevails an equal fauna throughout the Russian and West-European Jura is at least an exaggeration. According to the lists of fossils given by him, the differences mentioned by Neumayr are certainly present. On the other hand, Nikitin proved the existence of Reef-corals in the Russian province, and although these corals occur only in a few localities, and although Neumayr does not notice properly this point in his

reply to Nitikin's objections, regarding the presence of these animals as not conclusive, we must regard this point as very important, as we shall see below.

III. Neumayr continues in his argument by attempting to prove that these faunistic differences cannot be due to *topographical* causes. First he says that these three provinces could not be separated from each other by land. This relates especially to the limits between the Mediterranean and Middle-European provinces, while for the Middle-European and Russian provinces it was only partially the case. In the latter, at the formation of the Callovien-beds, first there was an open communication of the seas, later, after the Oxford-group, the Russian basin was closed on the west. We make no objection to this part of Neumayr's views.

Further Neumayr says that a second cause of a separation can be found in the different depths of the respective seas. Between the Middle-European and the Russian seas such differences are out of the question, because both were seas of shallow water. Between the Middle-European and Mediterranean provinces, however, differences of depth were certainly present. At least as regards the *Aptychus*-limestones, it is sure and generally accepted, that these peculiar deposits were formed in deep water, and further, Neumayr himself concedes that such a supposition has a "certain probability" (1871, p. 523) also for the subcarpathian and subalpine localities showing the peculiar Cephalopod-beds of the Mediterranean Jura, since the situation of the latter is an intermediate one between the *Aptychus*-beds on the one side and the Middle-European deposits on the other "formed in considerably shallower water." In spite of this, he believes that this supposition is not justified, since in some localities on the northern border of the Mediterranean province, especially near Stramberg in Moravia, where the Coral-reef facies prevails, among the Ammonites the typical Mediterranean genera, *Phylloceras* and *Lytoceras*, predominate. Therefore he concludes (1871, p. 524): because on certain localities on the northern border of the Mediterranean province corals are found in Cephalopod-beds, differences in depth of the sea cannot be the cause of the faunistic differences of the Mediterranean and Middle-European Cephalopod-beds.

This conclusion is incorrect. From the condition of the Stramberg-strata we learn only, that there is a mixture of the Coral-facies and the Mediterranean Cephalopod-facies.\* Neu-

\* Mojsisovics stated once (Verhandl. K. K. geol. Reichsanst., 1867, p. 187, 1868, p. 127 and 438) that even in this locality the Cephalopod-beds and the Sponge and Coral-beds are not mixed up, but that the former underlie the latter. But

mayr gives no explanation of this peculiar mixture. Regarding, however, the local position of these beds, quoted by himself, on the narrow limits between the Middle-European and Mediterranean Jura, that is to say, between the deposits formed in shallow water and those formed in deeper water (Aptychus-beds), we must assume undeniably that in this region in question the precipice of the sea bottom must have been situated: a *Jurassic Continental border* must have been present there! Then there are only three cases possible. Either the Mediterranean Cephalopod-facies is present there in shallow water, as Neumayr seems to suppose. Or the Coral-reefs grew there in deep water, which is very hard to believe. Or there was present a third condition, namely, the Cephalopod-beds of Stramberg were deposited like the other Cephalopod-beds of the Mediterranean province in deep water, but the corals and other fossils indicating shallow water did not live there, but were transported thither. Such an occurrence can be imagined the easier, since these beds are situated on the continental border, and if the precipice of the sea bottom was a steep one, Coral-fragments from the Coral-reefs living in an upper level, and specimens of the other shallow-water-fauna could roll down to the bottom situated in a lower level and could be deposited in the Cephalopod-beds formed there. That such conditions were actually present in that locality is confirmed by the petrographic nature of the Stramberg-limestone, as described by Böhm (l. c. 660). According to him this limestone often may be called a breccia, and, indeed, respecting one place he says: "Angular, larger or smaller fragments of a light gray limestone are embedded here in a dark gray to pitch black matrix. *The light gray limestone is filled with Corals,*" ("ist von Korallen förmlich durchspickt.") \*

We need no more evidence for the supposition made here. The conditions of the Stramberg-beds, quoted by Neumayr as adverse to the theory of a formation of the Middle-European and Mediterranean Cephalopod-deposits in different depths of the sea, prove to be a support of this theory when we consider the situation of these beds and their petrographic character.

Besides there is a third topographical cause, which may be held responsible for differences of faunas deposited at the same time: the different characters of the facies. Neumayr alludes to this point only incidentally, and generally he passes over it without giving it due consideration. Concerning the Mediterranean and Middle European provinces he says

this fact lacks confirmation. According to Böhm (Die Bivalven der Stramberger Schichten. — Palæontographica, Suppl. II. 4. 1883 p. 660-662) the different faunas are really found in the same rocks.

\* The italics are mine.

directly (1871, p. 521), that there are present palæontological differences between deposits of both "with the development of facies and conditions of formation apparently in complete agreement" ("bei offenbar ganz übereinstimmender Facies-entwicklung und Bildungsverhältnissen"). The facies of these two provinces are, according to him, "apparently" the same, but he does not give any proof for it. It is true, limestone-facies prevail in both, and it may be that Neumayr thought of this fact. There is, however, no doubt that all the known limestone-deposits were not formed under the same conditions; the Coral-limestones and the Cephalopod-limestones of the Middle-European province are certainly different facies; the *Aptychus*-limestone of the Mediterranean province is characterized by its petrographic nature (Hornstone limestone) due to the presence of silicious matter, and the Cephalopod-limestones of the latter province are also probably different. It is well known that all these deposits are different petrographically, and after a more close, especially microscopical examination, we will be, perhaps, enabled to find out the causes of their differences.

Yet we do not need much to urge these differences in these two provinces, as we saw above that the main differences are given by the different depths of the respective seas. To distinguish the Middle-European and Russian provinces, however, we have to direct more attention to the facies. The differences of the facies in the two latter provinces are wholly neglected by Neumayr, although they were pointed out most vigorously by Lahusen\* and Nikitin.

It was a well known fact, even to Neumayr, that in the Middle-European province limestones prevail, especially if we consider the upper strata (1890, p. 316), while in the Russian Jura "more soft clays and sands" (p. 326), and only "in an inferior degree limestones" (p. 327) are found. This prevalence of sandstones, especially in the Aucella beds, is stated by Lahusen several times (l. c. p. 486, p. 491, p. 492), and Nikitin (l. c. 1886, p. 211, p. 237) even holds this peculiarity of the facies responsible for the faunistic differences. It is further a very interesting fact given by Nikitin (p. 217, p. 234, p. 236), that corals are found in some places of the Russian Jura, and these are true Reef-corals belonging to the *Thamnastræidæ*. Neumayr refers (1887, p. 72) to this statement only by saying, that the occurrence of corals in Russia is "very rare," and that (p. 73) against the view that conditions of the facies play part here "grave doubts exist" ("schwere Beden-

\* Über die jurassischen Bildungen im südwestlichen Teile des Gouvernements Rjäsan.—Neues Jahrb. Min. Geol. Pal. 1877.



ken gegenüberstehen").\* The statement of Nikitin, however (p. 232), that calcareous deposits are almost absent in the Russian Jura, but that where such are exposed corals are found, induces us to accept a causal connection between the two facts. The occurrences of corals is connected with a calcareous development of the facies, and in the Russian Jura, according to the prevailing sandy nature of the deposits, only local formation of Coral-reefs and limestone-deposits was possible.

The fact that the Aucella-beds are mostly sandy deposits strengthens this supposition so much more, as these beds are wanting in the limestone-facies of Middle-Europe. Thus we are amply justified in looking at the differences in the character of the facies as the cause producing the faunistic differences of the Middle-European and Russian provinces even in the Ammonite-fauna.

By these considerations, I think, I have proved that the argument given by Neumayr for the non-existence or non-action of topographical differences upon the distribution of the Jurassic faunas is a complete failure. Only one point may be granted, that a separation by land was not present in an extensive manner. On the other hand we have learned that it is in the highest degree probable, that on the one side differences of depth of the seas, on the other differences of the facies, are the laws governing the faunistic differences. The first cause applies especially to the distinction of the Mediterranean and Middle-European provinces, the second to that of the Middle-European and Russian (Boreal) provinces.

IV. We have still to examine the third point in Neumayr's argument. As a corroboration of the climatic nature of the differences of the Jurassic faunas, he points to the distribution of the different provinces on the earth, which he alleges to be generally parallel to the equator all around the earth, thus forming circumpolar zones. This is the weakest part in Neumayr's view, especially because most of the extra European Jurassic deposits are very unsatisfactorily known, and because Neumayr himself was already acquainted with some localities contradicting his theory.

Neumayr attributes some significance to the supposed fact, that in South Africa and South America Jurassic deposits are said to be present, corresponding in their characters to the

\*In his latest rejoinder to Nikitin (N. J. M. G. P. 1890, 1, p. 142) Neumayr refers to his former paper (1887) as having shown that differences of this kind were not to be held responsible for the faunistic differences. But he did not even attempt to prove this assertion in that paper.

Middle-European features, thus indicating a similar (temperate) zone on the southern hemisphere. But he himself gives different opinions concerning these localities: once (1890, p. 330) he says, that the so-called Uitenhaage-formation, near Port Elizabeth, Cape Colony, has a fauna of Middle-European "habitus," and again (p. 333) he says, that the same formation has relation neither to the tropical African localities nor to those in Europe, while relations to some localities in East India (!) and South America (in the Andes of Chili) are apparent. All we know of the latter locality\* is that there are present species of *Phylloceras*, *Lytoceras*, and *Simoceras*, thus showing a more likely relation to the Mediterranean than to the Middle-European Jura, as supposed by Neumayr. At present, indeed, we may better disregard all these localities, as our knowledge of them is very incomplete.

Further, Neumayr himself concedes the Middle-European character of the Jurassic deposits of the Hermon, Syria. This occurrence, so absolutely opposed to his theory of climatic zones, he tries to explain in a very forced manner, supposing arbitrarily a southern local extension of the Middle-European Jura into the equatorial zone. We may add here that the Jura of Cutch, India, is regarded by Waagen as Middle-European, while Neumayr claims it as Mediterranean.

In this respect a recent paper of Tornquist,† treating a Jurassic locality on the eastern coast of Africa, near the equator, is very interesting. Tornquist says (p. 23): "As far as we know the fauna of Mtaru, it must be regarded surely as being of Middle-European character." Thus we would have there, near the equator, a Jurassic fauna, which, according to Neumayr, can only be found in much higher geographical latitude. As the fauna of Mombassa, situated in the neighborhood of Mtaru, shows relations to the East Indian localities, which are according to Neumayr Mediterranean, we have there, on the eastern coast of Africa, Jurassic deposits of either character closely approaching. Further, if we consider that Tornquist makes mention (p. 7, p. 25) of a peculiar facies of the strata of Mtaru, suggestive of the so called "terrain à chailles" in Middle-Europe (limestone-concretions in marl-deposits), we are again led to the opinion that differences of the facies take part in making up the faunistic differences.‡

\*See Gottsche, Ueber jurassische Versteinerungen aus der argentinischen Cordillere.—Palæontographica, Suppl. III. 1878.

† Fragmente einer Oxfordfauna von Mtaru.—Jahrb. Hamburg, Wiss. Anst. X. 2, 1893.

‡ We may quote here the following interesting remark of Tornquist (p. 25): "It seems that there is repeated the fact which is known in the Jura of the different countries and which is always equally astonishing, namely, that even over great distances a faunistic agreement of the different zones of the Jura can be accompanied by a lithological one."

The tracing of the different Jurassic zones around the other parts of the earth, especially across the American continent, is so problematic, that it is not worth while to go more into details here.\*

The instances, however, given above are wholly sufficient to conclude, that a circumpolar arrangement of the different Jurassic faunas is not yet proved; on the contrary, that some facts are known wholly dangerous to that theory.

V. But even in the case, that it may be granted, that it is neither proved nor refuted, whether the differences of the Jurassic faunas are due to topographical or to climatic causes, and even if we suppose that the action of the latter may have been possible, we will find that such a supposition meets difficulties hard to solve.

1. As we have seen above, Nikitin recognized the presence of Reef-corals in the Russian Jura, that is to say, in Neumayr's *Boreal* zone. Neumayr indeed denies the value of the Reef-corals as evidence for forming an opinion as regards the temperature of the sea water, but as I pointed out above, the Reef-corals are the only group of animals allowing a somewhat sure conclusion as to the former climatic conditions, and I can not strongly enough emphasize that I differ in this respect entirely from Neumayr. Therefore, I am convinced, that the presence of Reef-corals indicates a warm, and especially an equally warm temperature of the seas inhabited, such as now prevails in the tropical seas. If such a temperature was present in the *boreal* Russian basin, we have to ask: what kind of temperature-conditions prevailed in the *temperate* and *equatorial* zones of the Jurassic time? Then we would be induced to believe, that the equatorial seas of the Jura possessed a degree of heat which, compared with the recent conditions, would not have permitted at all the existence of animal life!

2. If we compare the temperature zones of the recent seas † with the supposed temperature zones of Jurassic age as constructed by Neumayr (1890, p. 336), we shall find that the latter are nearly the same as the former, at least as regards their distance from the equator. Even in some cases in Neumayr's map such places belong to a cooler zone, which are nowadays warmer. For instance, New Zealand and Port Elizabeth are situated in his map distinctly in the temperate

\* The occurrence of Aucella-beds like the Russian is indicated by Nikitin (Neues Jahrb. Min. Geol. Pal. 1890, II. p. 273) in tropical America, near St. Luis Potosi, Mexico. If this fact should be confirmed, it would prove an additional argument against Neumayr's theory.

† See the map accompanying my book: Grundzüge der marinen Tiergeographie.

zone, while they lie now, if not within the tropical zone, at least on the border of it. An arctic zone can be distinguished in the present seas only with difficulty from the temperate zone: Neumayr's *boreal* zone extends so far southward, that it is hard to believe that it existed at all.

According to our knowledge of the climatic conditions of former times, especially of the Tertiary age, there was a gradual decreasing of the temperature of the earth, beginning at the poles, and we are accustomed to believe that the climatic conditions now prevailing form the most extreme degree of cooling ever present on the earth. Then it would be impossible, that at any time in the past a climate existed which was cooler or was more differentiated than the present climate.\* Especially, we can not make such a supposition for the Jurassic age, passed by long ago, and the climatic conditions of Neumayr's map agreeing with the recent ones are utterly impossible. This striking improbability is the more conspicuous as we compare the supposed Jurassic climate of Neumayr with that of the older Tertiary times, as I have already done elsewhere.†

In the passage just referred to I remarked, that Neumayr perhaps intended to express no judgment of the actual temperatures at Jurassic times, but that he had in mind only that a *difference* in temperature was present. But then we would be induced to accept for his boreal zone a climate like that of the recent tropics, and we would be confronted with the same difficulty as discussed under No. 1.

3. Remembering the climatic conditions of the recent times we find, that climatic limits generally are not very sharp, but that there are zones of transition interposed. The limits of Neumayr's Mediterranean and Middle-European provinces are very sharp, so that we can not expect that there prevailed normal conditions. Neumayr himself is aware that these limits are unusually sharp ones, and he explains this fact by supposing that there was a current of warm water present. This supposition, however, is a pure imagination, supported absolutely by nothing.

4. But we will examine this current-theory more closely. Neumayr says (1871, p. 525), that this current coming from the South-West reached in the neighborhood of Cracow its most northern point, and curved then in a south-easterly direction—or the course of this current was in the opposite direc-

\* Perhaps one would refer to the conditions of the "ice age" as representing the most extreme cooling: but I remark explicitly, that I regard the so called "ice age" as a local feature of the subrecent time, which is not at all related to the general cooling of the earth.

† Grundzüge der marinen Tiergeographie, 1896, p. 62, 63.

tion. Such a current is according to his map hardly possible. The course in the direction first mentioned is impossible, because no conditions in the configuration of land and sea were present there which could effect a current in this direction (like the Kuro-Siwo and Florida current of recent time). The alleged curve of the current at its most northern point would be also astonishing: why does this current not carry its warm water farther northward into the Russian province? If it went in the opposite direction, we must ask: where did it come from, and what was the cause producing such an abnormal movement of water in a direction never displayed by any important current of the recent seas? And a current effecting such striking and sharp differences of temperatures must necessarily have been an important one!

I think, however, there is no profit in trying to construct the ocean currents of Jurassic age. But if we adopt the configuration of land and sea given in Neumayr's map, there can be no doubt, I believe, that only *one* kind of movement of the surface water of the sea was possible in all these parts under discussion, namely a general current running from East or North-East to the West or South-West. Then from the Russian basin a cool current would run into the Middle-European and Mediterranean provinces, and the course of the northern limits of these two provinces should be very different from that given by Neumayr. These limits could not show a convexity toward the North just opposite the main opening, through which the cool water was discharged, but we should expect a southward curve of these lines.

Under such conditions of things, since it is at present utterly impossible to get an approximate idea of the Jurassic currents, it would be profitable to have recourse to such theories only in the most desperate cases, where no other explanation is possible.

The results obtained by these considerations may be summed up as follows. The differences observed in the faunas of the Jurassic deposits are not caused by climatic differences. The arguments of Neumayr for the non-action of the topographical conditions are partly incomplete, partly they fail to convince. On the contrary, I have shown, that even conditions of the latter kind, differences of depth of the seas and differences of the facies play the chief part in influencing the distribution of the Jurassic fauna, and that the existence of climatic zones in the Jurassic seas is not only not proved, but extremely improbable. Therefore it would be well to abandon entirely Neumayr's theory of climatic zones in Jurassic time,\* and it would

\* In order to prevent any misunderstanding, I wish to say expressly, that I do not deny the existence of changes in temperature and differences in climate in

be more profitable to examine closely the differences of the facies of this time, especially the question, how the different facies are deposited, and how the different groups of animals are influenced by the facies. There is no doubt that for this purpose we have to compare the fossil deposits with those formed in the recent seas. This latter method is the way outlined by J. Walther in his work: "*Einleitung in die Geologie als historische Wissenschaft*," and it would be very advantageous to direct more attention to this subject in subsequent geological studies.

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pre-Tertiary times. But such changes and differences of the *ocean-waters* were only slight ones, not differing from those present nowadays within the tropical seas, and not influencing the distribution of animals. On the other hand, the *air-temperatures of the continents* changed even in pre-Tertiary times in proportion to the size of the continental masses to the elevation and to the geographical latitude. Perhaps they did so in a lesser degree than at present, but this difference of the oceanic and the continental conditions of temperatures was almost as striking as it is nowadays between the temperatures of the recent tropical seas and those of the high mountain-chains and table-lands of the tropical parts of the recent continents.