THE CANON OF MARINE TRANSGRESSION IN POST-PALÆOZOIC TIMES.

By J. S. Lee.

I. *Introduction*

In attempting to attack the fundamental problem of geotectonics, the writer has endeavoured to show, along very broad lines, that the more important marine transgressions in the Northern Hemisphere during the Palæozoic Era are conducible to a certain rule, that is, prior to an episode of orogenic movement marine water generally transgresses in the low latitudes, and regresses from the high latitudes; whereas during or immediately after the diastrophism the movement of marine water is generally reversed [69]. It was left to be demonstrated whether a similar order of things prevailed in post Palæozoic times. This forms the subject of discussion in the present paper. As we are in possession of greater detail of post Palæozoic stratigraphy, the several cases are more fully discussed than before. But the enormous mass of data involved makes it quite impossible to treat the subject in this short review with desired thoroughness. Moreover much is yet to be done regarding the stratigraphy of the Arctic regions which, for certain reasons, ought to be the more sensitive parts on the globe to testify to the oscillatory changes of the oceanic figure.

During the preparation of the present paper, the writer has found much encouragement in the authoritative work of Professor C. Schuchert on the "Palæogeography of North America" and his more recent writing on the "Site and Nature of North American Geosynclines". The problem of oscillatory marine transgression was apparently seriously considered by Professor Schuchert and his late colleague, Professor J. Barrell (if Professer Schuchert is herein rightly understood). Unfortunately the writer remained ignorant of that vital part [113 a] of their illuminating discussion until quite recently when he had an opportunity to consult Professor Schuchert's full paper on North American Palæogeography.

At the same time some difficulty has been encountered in following the theory of compensatory transgression [51] so emphatically advocated by the late illustrious Haug. This, however, does not mean that Haug's idea is altogether irreconcilable with the writer's contention, because compensatory movement of a water body in the neighbourhood of a geosyncline can very well take place while the oceanic surface is effecting a grand oscillation. Dr. H. Stille's argument [115] on the contemporaniety of transgressive or regressive movement and orogenic folding can be taken as a step toward our conclusion so long as it is not categorically maintained that transgressions were simultaneously effected to an equal extent in all latitudes and for all times.

We must not, however, suppose that the oceanic figure alone could be deformed to any extent, because the mobile mass of the ocean is under all circumstances controlled by the gravitation potential as is clearly set forth in Clairaut's theorem. In other words, the deformation of the oceanic figure cannot be expected to exceed a certain extent without being accompanied by a corresponding deformation of the figure of the lithosphere. The actual differential amount of deformation depends upon the deformability or the strength of the lithosphere. The whole problem is highly complex, and evades simple treatment even if we start with certain mathematical assumptions. It is only through the comparative extent of marine invasion in the high and low latitudes during two successive periods of time that we begin to realize such grand oscillations.

Nor is it safe to disregard the changes produced by local or regional subsidence or elevation on the part of land-surface as a consequence of tectonic "evolution" or "revolution." If the absolute amount of lowering of the land-surface exceeds that of the negative movement of sea-level, the area concerned would then, no matter where it is situated, be submerged. Such an area is generally an active geosyncline or a synclinal basin, and can therefore be recognized as such, though perhaps with some difficulty. For this reason, no great evidential value can be attached to the distribution of the epeiric waters during a period of great revolutionary upheaval when the whole of the continental blocks were more or less continually undergoing a profound change such as in the Permian and Neogene.

Before entering on detailed discussion, it should be noted that throughout the analysis of the data assembled here, no assumption is made of extensive pole-wandering. A limited displacement of the poles, say within the scope of ten to fifteen degrees, would not however materially affect the general conclusion to be drawn. Certain tectonic as well as transgressional phenomena are indeed better explained if we assume that the equator lay, with reference to the African Continent, about ten or at most fifteen degrees to the north of its present position in Mesozoic and Tertiary times.

II. *Review of Evidence.*

A. TRIASSIC.

As a result of the grand tectonic revolution toward the close of the Palæozoic Era, the continental blocks as a whole obviously underwent a considerable uplift. Continental depressions in the Northern Hemisphere that were filled with marine water at one time or another during the Triassic Period, were but few in number, relatively restricted in extent: and in the case of those which only had a boreal connection, the stratal history is yet by no means clear. So far as the Eurasian Continent is concerned, there seem to have been two cycles of oceanic oscillation within this period. The first closed in the Ladinian and the second the Norian. Evidence, or at least indications, for these oscillations are best found in the Alpine Trias, and in certain cases in the Indo-pacific and boreal provinces. The Germanic province being situated in between the boreal and Mediterranean basins, furnishes no conclusive evidence.

The general character and succession of the Triassic formation in the Alpine Geosyncline are best summarized by Haug in the following terms [52a]:—

4. Norian Stage, an epoch of very general calcareous sedimentation

3. Carnian Stage, a "lagoonary *régime*", everywhere, except the axial part of the geosyncline, characterized by chemical or detritus sedimentation, often charged with vegetable debris.

2. Middle Trias, an epoch of calcareous sedimentation which proceeded in certain places almost uninterruptedly.

1. Lower Trias, an epoch of detritus sedimentation.

From this stratigraphical summary, it is to be deduced that in the Lower Triassic time, there was a general regression; in Middle Trias, transgression; again at the Carnian Stage, regression; this was followed by the Norian transgression with which closed the Triassic Period. This condition does not only hold in the Alpine Geosyncline proper, but appears to extend into Carpathian [128, 35] and Crimea. The Ladinian is sometimes reported to be absent, but more careful investigation has shown that that stage is very often represented in those places by unfossiliferous or almost unfossiliferous dolomite [74].

The Himalyan Geosyncline apparently remained to be a deep water basin throughout the Triassic Period, though careful stratigraphical research may bring out breaks of import. The *Tropites* Limestone of Byans suggests, for instance, the existence of a break within the Upper Carnian or Lower Norian [22]. It is in the north-eastern extension of the Himalayan Geosyncline that we find definite evidence for the expansion of the Muschelkalk water. This is shown by the stratigraphical development in south-western China. What happened in the southern and south-eastern part of Europe is thus, at least partly paralelled in southern Asia.

For comparing the southern conditions with those of the high north, let us take the stratigraphical summary for the Triassic development in north-eastern Siberia given by Obrutchew [87a]:

Upper Trias:

6. Rhaetic. Wanting.

5. Norian. Distributed in the northern and southern coastal districts of the Ochotsk Sea, Verchoyanski Mountain, Yana Basin, New Siberian Islands and probably Olenek Valley, consisting of alternating beds of black, clay-shale, sandy shale and sandstones, and sometimes quartzite and conglomerate. The sandstones often yield plant remains, and the shales contain numerous pelecipods, especially *Pseudomonotis ochotica*, some brachiopods and rarely cephalopods.

4. Carnian. Distributed in the north coast of the Ochotsk Sea, Yana Basin (along the river Dulgolach) and the Kotelny Island, consisting of shales and limestones with *Halobia fallax*, *H. zitteli*, *Pseudomonotis and Schizoneura.*

Middle Trias:

3. Ladinian. Wanting.

2. Anisian. Distributed in the neighbourhood of Vladivostock (Rasdolnaya, Russki Island) and in the Kullar Mountain, on the lower reach of the Yana and the Mouth of the Olenek. In the neighbourhood of Vladivostock, this stage is represented by marl, shale and sandstones with *Ptychites*, *Xenodiscus*, *Monophyllites*, *Pseudomonotis*, *Pecten*, *Lima*, *Lingula* etc.; in the high north, it consists of calcareous and sandy shales and rarely sandstones with *Hungarites*, *Beyrichites*, *Parapopanoceras*, *Spiriferina*, *Rhynchonella* etc.

Lower Trias:

1. Scythian. Represented in the southern part of north-eastern Siberia, along the Amur Valley and the Russki Island, by sandstones, conglomerates, and shales with *Meekoceras*, *Myophoria*, *Myalina*, *Pecten*, *Pseudomonotis* etc. This formation attaining a thickness upward of 1000 m., probably covers the whole of the Lower Trias; whereas, in the High north, *i.e.* in the lower reach of the Olenek, Kotelny Island, and along the northern coast of the

Ochotsk Sea, conglomerates only seldomly occur, the prevailing type of rock being shales and sandstones. These strata contain numerous cephalopods, such as *Meekoceras, Xenodiscus, Monophyllites, Czekanowskites, Keyserlingites Olenekites* etc. probably representing upper Scythian.

The Ural or its sequent Geosyncline was probably submerged in the Lower Triassic time. The whole of that hypothetical water-body had undoubtedly disappeared since the early part of the Middle Triassic. Whether that area was again submerged sometime in the Upper Triassic is a matter that for the present must be held with doubt. The discovery by Dr. J.G. Andersson of a *Myophoria* formation in the Bear Island [2] is however a fact of considerable interest from our point of view, because the fauna obtained by Andersson, including *Clionites, Dawsonites,* indicates Carnian transgression. In Spitzbergen, the Triassic development, though yet ill understood, offers some interest for comparison. The Isfjord Series which directly overlies the Permian, is reported to be overlain by a bituminous limestone with *Posidonomya minor, Meekoceras furcatum, Monophyllites spitzbergensis* etc. apparently of lower Virglorian age [75]. This is in turn overlaid by a black shale with *Daonella linströmi, D. arctica, Ptychites* and *Parapopanoceras,* a fauna apparently comparable with that of the Anisian of N. E. Siberia. The occurrence of a bituminous shale in Mont Tschermak with *Halobia zitteli* recalls the Carnian in N.E. Siberia.

Thus it would seem that during the Lower Triassic time when a regression of marine water took place in the Alpine Geosyncline, parts of N.E. Siberia, Spitzbergen and probably part of the Ural sequent Geosyncline were under marine water; that during the later part of the Middle Triassic epoch when there was a general inundation in the southern seas, there was a compensatory regression in the north; that when a "lagoonary *régime*" prevailed in the Alpine Geosyncline in the Carnian time, there was a transgression in Spitzbergen and perhaps in N.E. Siberia as is shown by the deposition of calcareous and argillaceous sediments; and finally that the Norian transgression took place in the southern seas, but in the high north, this stage was only represented by continental deposits or detritus material. It remains to be seen whether similar relations hold for the movement of the epeiric waters of the North American Continent during the Triassic time. For a strict comparison, we have yet to wait for a detailed stratigraphical investigation of the marine Triass of Arctic North America.

B. JURASSIC.

Inasmuch as the zoning work of the Jurassic formations has been carried out in some detail over large areas of the world, particularly Europe, we can follow the movement of the oscillatory seas of this period with some accuracy. There were at least two cycles of oceanic oscillation during the Jurassic Period. The first of these constitutes the Lias, and the second, the Oolite. Minor oscillations may have taken place towards the end of the Oolite time; but they are not, at all events, comparable, in extent or duration, with the two major ones.

(a) Liassic Cycle.

For convenience, we will first deal with the southern seas. In the Mediterranean region, the development of the Lias is somewhat varied in different areas. Within a few basins, the several stages of the Liassic formation succeed one above the other without any detectable break, such as in the Tage district, Portugal, the neighbourhood of Digne, the Dauphic Basin, Lombardic Alps and Dinaric and Apennine geosynclines. In the Aquitanian and the Rhône Basins, the succession is almost complete; only the higher stages of the Lower Lias are absent. These are, however, exceptional cases. As a general rule, we may say that the Liassic sea became transgressive from the Domerian upward. Thus in the Teruel Province, northern Spain, neritic Domerian Limestone sometimes rests directly upon Hettangian dolomite and sometimes on the higher stages of the Lower Lias [23]. At the northern entrance of the Rhône Basin or "Golfe des Causses" a transgressive sandy limestone of Domerian age is separated from the Sinemurian sometimes by a conglomerate and sometimes by a marly limestone (104). Similar stratigraphical relation appears to persist in Basse-Provence, though, there, the transgression may have started somewhat earlier. In the Venetian Alps [79] and Transylvania, the higher zones of the Domerian are also decidedly transgressive.

It is however during the Toarcian and Lower Aalenian times that the Liassic sea became most extensive in the Mediterranean region. For palæontogical records show that the famous Rosso Ammonitico Limestone and its equivalents extend over the Lombardic Alps, large areas of Italy [76,3], southern Spain, and reaches as far south as the Traras Massif and Benisnassen district on the Moroccan frontier (42). In Calabria, the higher stages of the Lower Lias as well as the Middle Lias are entirely unrepresented. The Toarcian and Aalenian stages often directly rest upon eroded granite [44]. The Briancon area which stood above the water between the Dauphinic Basin on the west and Piemont Basin on the east, was by this time also submerged.

Evidence of Toarcian and lower Aalenian transgression is further recorded in Cracow [105], the Dontez Basin, Balkan, Crimea [4], East Africa and Himalaya where the Upper Liassic is probably represented by the main body of the Kioto Limestone of great thickness. In the Isles of Rotti, near Timor, the ejected material from volcanoes furnishes positive evidence of the existence of the Lower Lias and the Toarcian, the presence of the middle Lias being highly problematic [106].

In the Arctic region, marine Lias is rather poorly developed. And of the few areas wherefrom marine fossils have been obtained, our knowledge is as yet insufficient to permit us to form any definite idea as to the nature and succession of the Liassic strata. Between the Chatanga and the Lena, Toll and Tolmatschev obtained a number of fossils which, according to Pavlow [91], are partly to be assigned to the Middle Lias, Lower and Upper Liassic forms being absent. The Aalenian stage with *Harpoceras murchisonae* is represented in the Vilui Basin by argillaceo-arenaceous strata being overlaid and underlaid by fresh water deposits [59]. A marine Liassic formation probably exists in the Yana Basin; but its exact stratigtaphical position is yet unknown.

On the other side of the globe, marine "Upper Lias" is reported to occur in Prince Patrick Land. The fossils obtained (*Harpoceras macclintocki Monotis septentrionalis*) furnish, however, no conclusive evidence as to its exact stratigraphical position [113b]. In the south-western part of North America, evidence of upper Liassic transgression is found in northern California [54] where the Hardgrave Sandstone with a marine fauna directly overlies the Trail Formation of continental origin. That this submergence is not of local character is indicated by the presence of a thick Liassic limestone in western Nevada, and of a marine argillaceous formation in the Puebla and Vera Cruz areas [5].

These facts indicate that from the later part of the Domerian up to the early part of the Aalenian time, or briefly during the Upper Liassic epoch, there was a general positive movement of sea-level in the low latitudes. It remains however to be proved whether the floods in the Chatanga-Lena area and in the Vilui Basin preceded and followed respectively the expansion of marine water in the south. Whatever happened to the north, the evidence is fairly conclusive that there was a general expansion of the southern water in the later part of the Liassic epoch.

(b) Oolitic Cycle.

As in the previous case, we will first review the more important stratigraphical results obtained from the southern regions, and then proceed to discuss the evidence from the north. On the northern border of Iberic Meseta, northern Spain, a continual sequence of the Bajocian to the Callovian is developed in the Terual Province. And again all the different stages ranging from the Argovian to the Kimmeridgian, are represented by fossiliferous deposits in the Aragon area. This sequence is capped by an unfossiliferous sandy limestone questionably assigned to the Portlandian. The Oxfordian is totally unrepresented [23]. Similar development holds in the Aquitanian Basin; only, there, the Callovian is but slightly developed, and the Portlandian is fossiliferous proving that the latter belongs to the Lower Zones of that stage, or the Bononian.

On the border of the Central Plateau of France, particularly the north-eastern part of it, the Oxfordian is again wanting, and the lower zones of the Bajocian are also unrepresented. Otherwise the Oolitic formation is fairly complete [52b].

Around the Rhône Basin, a complete succession is found ranging from the Bajocian to the Callovian. These are succeeded, in the "Golfe des Causes", by the Argovian up to the higher zones of the Kimmeridgian. The latter is overlaid, in the "Vocontian Trough", by the Tithonian which merges upward into the Lower Cretaceous. The Oxfordian is however only slightly developed in the neighbourhood of Ardèche and a few other localities. As a rule, it is missing in and around the Rhône Basin [52c].

In the Dauphinic Basin, there is a complete sequence of strata ranging from the Bajocian to the Tithonian. Only a slight lithological change is here and there observed in the Lower Argovian. The Tithonian shows an overlapping tendency. In the marginal areas of the basin, the transgression of the Tithonian sea is obviously indicated by the fact that in the Embrunais and Ubaye Sheets, the Briancon Zone and Basse-Provence, the Tithonian rest directly upon the Lias [60]. Similar conditions seem to prevail further north, and probably be maintained in the Swiss Alps.

In Southern Tyrol [94] and western Carpathian [80, 129], the lower stages of the Oolite ranging from the Bajocian to the Oxfordian are completely developed; but the upper stages, namely, from the Argovian to the Kimmeridgian are unrepresented. The latter stages are however present in eastern Carpathian, Podolian Plateau (eastern Galicia) Gylkos-kö, (east of Transylvania) Dobrudscha and Armenia. In these places, the Kimmeridgian either overlaps the older formations (eastern Carpathian) or rest directly upon rocks of much older age.

In the Apennine region, the lower stages of the Oolite are largely represented by a massive limestone which is reported to contain *Reineckeia* and

Perisphinctes. This limestone is overlaid by the Aptychus Shale. A calcareous facies of the shale has yielded Kimmeridgian fossils at the Mont Serra, Toscana, overlying, in the last-named locality, upon Lower Lias [14]. The Tithonian is clearly transgressive both in the Apennine and the Sicily areas.

A fairly complete succession of the lower and middle Oolite appear to have developed in Caucasus, Crimea (Sondak), Trans-Caspian (Manguychlak) and Donetz. But in Caucasus the higher zone of the Kimmeridgian is missing [81]; and the Tithonian or Volgian directly overlies the lower part of the Kimmeridgian In Crimea, the Tithonian sometimes rests, with a basal conglomerate, on folded lower Jurassic strata [107] and sometimes on crystalline schist as in the southern Carpathian. The Kimmeridgian is probably unrepresented.

In North Africa, the Argovian transgression is recorded in northern Tunisia, the Province of Constantine and the Uarsenis massif. In these places, the Argovian generally rests on the Lias; only isolated outliers of the Sequanian now and then occur. To the south of the Atlas, Bajocian and Bathonian are often developed. In the extreme southern part of Tunisia, a limestone or dolomite formation has yielded fossils that range from the Bathonian to Kimmeridgian in age. To the south of Algeria and Oran, the Argovian-Kimmeridgian sequence directly rests on the Trias or eruptive rocks, and underlies overlapping Tithonian [52d].

In Abyssinia and Somaliland, the Bajocian and Bathonian sequence is in many instances followed, with a pronounced break, by the Kimmeridgian [38, 27, 24]. Similar stratigraphical relation appears to persist in S. W. Arabia and Palestine. Recent researches have shown that marine Kimmeridgian (Tendaguru Series) occurs in ex-German East Africa where it transgresses upon gneiss.

Lower stages of the Oolite are very poorly, if at all, developed in the Himalayas. The famous Spiti Shale may represent, in its lower part, the Kimmeridgian; but the fauna that it contains is certainly predominantly, if not exclusively, Portlandian. In the Cutch State, the lower stages of the Oolite are on the other hand well represented by the Patcham and the lower part of the Chart series which probably extends up to the Callovian. The Upper Chari and its overlying Katrol Series undoubtedly represent the Argovian and Kimmeridgian; for the Katrol Series contains a fauna closely related to that of the Kimmeridgian of the Alpine region.

In Sierras de Mazapil, Santa Rosa, Mexico, the marine Jurassic Probably begins with the Sequanian; Kimmeridgian and Portlandian are well developed. The former contains a fauna showing affinities with that of Central Europe, and the latter yields the typical boreal form, *Aucella*. as well as other species of Mediterranean derivation [6].

Having broadly surveyed the southern seas, we will now collect the fragmentary information from the north. On the east side of Greenland, in the Island of Khum, Bajocian and Bathonian are developed. Southward, at Cape Stewart, Jameson Land, Bajocian, Bathonian as well as lower Callovian are developed. Further south. Lower Volgian makes its appearance [77].

In his recent letter to Professor Schuchert, Dr. L. Koch affirms the fact that Lias, Callovian and Portlandian are especially well developed in East Greenland. Callovian and Kimmeridgian are also reported to occupy a large area in King Wilhelm Land. The presence of the latter stage in the high north is somewhat puzzling. It would however be useless to make any comment until the nature and exact stratigraphical position of the "Kimmeridgian" is definitely established [61].

At Cape Flora (lat. 80° N.), Franz Joseph Land, deposits of Bajocian upper Callovian and lower Oxfordian ages [82] have been found below basalts that are at times interbedded with continental strata which contain Upper Jurassic plants [95]. Similar conditions are maintained in King Charles Land [96]. Both in King Charles Land and Spitzbergen Lower Volgian also occurs.

In the Isles of Andö, one of the Lofoten Islands, marine Oxfordian overlies a coal-bearing series equivalent to that of Lower Oolitic age in Spitzbergen [67].

On the southeastern border of the Russian Platform, *i. e.* in Saratof and Kief and in Lithuania, Bathonian is developed. This stage is however not represented in the central area of the Platform. Thus in the Moscow district, a black shale of Upper Callovian age is unconformably underlain by the Moscovian, and followed upward by Oxfordian, Argovian and lower Kimmeridgian which latter is separated from the overlying Volgian by a distinct break [55]. There, the Volgian is represented by the upper zones of the Lower Volgian with characteristic *Pavlovia* and large *Perisphinctes*.

Further north in the Petchora Basin and Novaya-Semlya, stratigraphical records from the lower Callovian up to the highest Oxfordian with *Cardioceras alternans* are completely developed, but the Kimmeridgian is unknown. Volgian is again developed. The latter appears to spread eastward into the Liapin district [56], Sygva Basin, and Sosva area, on the eastern side of the Ural.

In the Riazan district the Volgian is also separated from the underlying lower Kimmeridgian by a break. Higher zones of the Kimmeridgian are only represented in the marginal areas of the Platform, especially the southern part of it. Thus in the Governments of Simbirsk, Samara, and Orenburg, the Kimmeridgian merges upward into the Lower Volgian or Bononian. The upper Volgian, or Aquilonian, is largely developed in the Volga Valley particularly in the area between Kachpur and Moscow, and along the Sosva Valley and its tributaries, the Lepsia, the Nyansa, the Uolya. In the latter area, the Volgian, according to Fedorow, is followed downward by a sandy clay containing marine fossils of Kimmeridgian age as well as trunks of fossil-wood and saurian remains. This is underlain by an Oxfordian clay [87b].

Between the Yenissei and the Lena, along the Arctic coast and the Lena Valley, there is an extensive formation with numerous *Inoceramus* and *Aucella*, formerly considered to be of upper Volgian age. But now they are largely proved to be a lower Cretaceous formation.

The fauna obtained by Toll and Tolmatschev from the area between the mouth of the Chatanga and that of the Lena, and determined by Michailski and later revised by Pavlow (91), shows the presence of lower Portlandian, Oxfordian and lower Callovian. Kimmeridgian forms are significantly absent. In the Islets in the Chatanga Bay, Callovian Oxfordian, lower Volgian, and Neocomian are developed, but Kimmeridgian is again absent [109]. The only marine Jurassic found in the Island Kotelny is of lower Sequanian age (*Aucella bronni*, *A. kirghisensis*). The marine Jurassic fossils found in Cape Vyssoki, New Siberia, are considered to be of Callovian age [91].

The Gryphaea-bearing shale (*crowded* with *Gryphaea* cf *dilatata*) exposed at Tyngehei, on the Yana as mentioned by Toll [123], extends, in all probability, over a considerable area in the Yana Basin, being overlain by a sandstone probably Neocomian age.

Bajocian and Bathonian occur at the mouth of the Byrandscha River on the southern coast of the Ochotsk Sea being represented by a coarse, yellow sandstone with *Oxytoma münsteri*. Upper Sequanian appears to be present along the River Elga.

In Peninsular Alaska, the Island of Kadiak and British Columbia, the Callovian is directly overlain by the Lower Volgian with *Aucella mosquensis* [97].

From the data enumerated above, it is possible to attempt some broad generalization as to the general movements of marine water during the Oolite time. We note with the exception of a few sinking areas or deeper basins such as those located in south-eastern Europe and North and East Africa, that the Oxfordian and some of its substages are not developed in the south; whereas Callovian and Oxfordian attain an extensive distribution over wide areas in northern Eurasia and North America. A large area in the north-western part of the latter continent was then submerged under the "Logan Sea" [68,114]. The absence of the Oxfordian formation from Greenland and elsewhere in the Arctic region may be explained by denudation during the Kimmeridgian time. Following the Oxfordian transgression in the north, there began in the south, the Argovian transgression which culminated in the Kimmeridgian time. The expansion of the Kimmeridgian water in the south is synchronized by a retreat of the sea in the northern areas. Even in the Sosva Basin where the Kimmeridgian is developed, the organic remains that it contains indicate shallow water or even terrestrial condition. In the central part of the Russian Platform, the lower Kimmeridgian is separated from the overlying Volgian by a distinct break.

Now comes the question of tectonic movement. There is abundant evidence to show that minor movements persisted from the Aalenian to the Bathonian time or even later. But the important orogenic movement of the Jurassic time did not break out until the close of the Kimmeridgian. The nature and extent of this movement have been fully discussed by H. Stille [115] and J. Lewinski from the point of view of European geology, and is to be correlated with the Sierra Nevada Orogeny in North America and the Yenshan Movement in Eastern Asia. Dr. Stille does not distinguish the several phases of this movement except in the region of Saxonian folding. From the scattered occurrence of the Berrias between the highest Tithonian and the lowest Valanginian in the south, it appears highly probable that at least an epeirogenic uplift occurred towards the end of the Portlandian time. This is tentatively regarded as the second phases of the Young Kimmerian Movement.

Thus we are enabled to conclude that after the post-Lias or during the Lower Oolite movement the open water bodily shifted to the north; that before the late Jurassic movment the open water expanded in the south but soon after that movement the open water again partly withdrew to the north leaving the Volgian deposit in the Arctic region.

The Tithonian or the southern Jurassic Sea, still continued to expand foreshadowing the second phase of the late Jurassic movement which actually broke out toward the close of the Volgian time.

C. CRETACEOUS.

Six distinct stages of marine transgression are now recognizable on the continental areas in the Northern Hemisphere during the Cretaceous Period. Of these, three are in the north or directed to the north, and the other three affect extensive areas in the south. Chronologically, the most important northern invasion took place in early Neocomian time; the other two of minor significance occurred in the Albian and Lower Senonian times. The first southern invasion took place in the late Lower Cretaceous (Neocomian). This was intermittently followed by the Cenoman-Turonian and the Upper Senonian or Maestrichtian transgressions. Other minor oscillations of sea-level may have occurred in between these epochs; but they are relatively unimportant when compared with those marked and more sweeping movements just referred to.

(a) Neocomian Cycle.

The Lower Neocomian transgression affects large areas in the Arctic region. In Greenland, marine deposits with Valanginian and Barremian forms occur in the Island of Kuhn [92]. In King Charles Land, marls with abundant *Aucella crassicolis, A. Keyserlingi, Belemnopsis cylindroteuthis* etc. overlie the Volgian [96]. Marine Valanginian is doubtfully present in Spitzbergen. With the exception of the Hauterivian Stage, the Neocomian formation is well-developed in the Petchora Basin, west of the northern Ural [93]. On the eastern foot of the Ural, glauconitic sandy clays or clayey sandstones of Neocomian age extend over the northern part of the Lepsia, the Tolya and the Liapin Country, on the River Sygva. These deposits overlie the Volgian with *Pavlovia*, and have yielded large *Exogyra* and *Blelmnite laternalis* in the dolomitic concretions that they contain [56]. Between the Tschaikina and the Karga, and near Prilutschnoye, in the lower reach of the Yenissei, calcareous and glauconitic sandstones were found by Lopatin and Schmidt containing numerous *Inoceramus neocomensis*. These occurrences together with the discovery below Dudino of boulders and slabs of a grey limestone and sandstone which have yielded Neocomian forms suggest that considerable areas in the Lower Yenissei were under marine water in the Neocomian, and probably early Neocomian time [87c].

Further east, the presence of marine Neocomian is indicated, in the Taimyr Peninsula, by the occurrence of rock-types similar to those of the lower Yenissei with numerous *Aucella* and *Astarte veneris*. Between the Chatanga and the Anabara, Tolmatschev found marine Neocomian with coals of inferior quality and rock salt and gypsum. The fauna which it contains, including *Simbirskite*, represents, according to Pavlow, Lower to Middle Neocomian [91]. Valanginian occurs in the Islets of Preobraschenie and Begitschev in the Chatanga Bay.

Between the Lower Olenek and the Lena, a Neocomian formation divisible into two stages was found by Tschekanovsky who thought them to be of Jurassic age, but they are now known to belong to the lowest Cretaceous. The Upper, or the Inoceramus Stage, consists of light grey or green sandstone with *Aucella crassicolis* [71] and *Inoceramus retrorsus* [70]; the Lower, or the Surak Stage, consists of black and dark grey shales with large concretions. These rocks probably extend up to the source of the Olenek.

Shales and Sandstones with *Inoceramus* and *Aucella* are widely distributed in the Lower Lena, Yana Basin, lower Aldan and in the neighbourhood of the Chara-uloch which is a name applied to that part of the Verchoyansk Mountain that lies between the Lena and the Yana Rivers. Over this vast territory, the Neocomian sometimes occurs as marine sediment, but sometimes it merges into lagoonary or even fresh water deposits.

Neocomian sandstone and shale with *Aucella crassa*, *A. keyserlingi* *A. volgensis*, *A. bulloides* etc. near the rapids of the upper Anadyr [98] and in the Pokulnei Mountain. This fauna, according to Pavlow, is typically Neocomian. Southward, lowest Neocomian (Berrias) is represented by sandstones and siliceous shales in the coal-bearing series of the Bureya Basin. The fauna which it yields consists of *Inoceramus* cf *ambiguus*, *inoceramus retrorsus*, *Belemnites*, etc., and its stratigraphical position is comparable, according to Schmidt, with the Surak Stage of the Olenek [110]. At the mouth of River Gorin, in the lower reach of the Amur, there occurs a black shale which has yielded *Aucella keyserlingi*, *A. inflata*, *A.* cf *volgensis*, *Inoceramus ambiguus* etc. As in the case of the Bureya Basin just referred to, there is not much doubt that the shale which contains those forms belong to the lowest Neocomian.

It appears therefore more or less established that large areas along the Arctic coast of Eurasia were submerged in the Neocomian or more precisely early Neocomian time. Arms of this epicontinental sea stretched far into the south on both sides of the Ural, along the valleys of the Yenissei, the Lena and the Yana. Parts of north-eastern Siberia were likewise under the Neocomian sea. The distribution of these waterbodies generally follows that of the upper Jurassic; but the former evidently covers a larger area.

Turning now to North America, we find again an extensive sheet of Neocomian marine water covering large areas of Alaska, marginal parts of

British Columbia [25], Queen Charlotte area and communicating with the Californian Sea on the south. In this Neocomian sea, the boreal fauna, particularly *Aucella crassicolis*, is so predominant up to the end of the Knoxville time, that Stanton has gone so far as to state that "they must have actually monopolized the sea bottom" [112]. Another characteristic boreal form found in the Upper Knoxville Series is *Simbirskite* which occurs in the Queen Charlotte Island and California in association with the Jurassic, particularly the Tithonian. That is, the Neocomian was either deposited in the pre-existing basins or in their neighbouring areas which subsided after the Young-Kimmeridgian Movement.

The same condition holds in western Portugal, Southern Spain, northern Tunisia and Algeria, the Rhône Basin and the western Alps, Central Apennine and Sicily, Bavaria, Carpathian (Subtatric, Piennine, Dealu Sasului) Banat and Serbia, Dobrogea, Crimea, northern Caucasus, Transcaspian (Manguychlak), western Baluchistan, Salt Range, British East Africa and Mexico.

In these areas where the southern Neocomian seas were largely distributed, we find no evidence, except on the border of the growing geosynlines, that the early Neocomian water expanded to any extent. Even in those areas where the Neocomian water tended to spread *northward*, *e.g.* in the Gulf of Mexico region [114a], the transgression is by no means comparable with the Arctic flood of the time. The Berrias Stage which is well represented in the north, attains even a more restricted development than the higher stages of the Neocomian in the south.

As to the succession of the southern Neocomian, we may note that in some cases, the Valanginian is absent, such as in the Southwestern part of the Rhône Basin, to the south of Languedoc, where the Neocomian begins with the Hauterivian Stage [116] The Barremian does not appear until we trace to the north of Gard and to the Hérault district [99]. In the middle belt of the Flysch Zone, in Manguychlak, in south-eastern Italy [117] and north-western Sicily, the Valanginian is either totally wanting or very poorly developed. In other cases, the lower stages of the Neocomian are only represented by shallow water deposit, such as in the marginal part of the Rhône Basin, Basse-Province and Crimea [65]. There isolated instances *per se* do not of course prove a general withdrawal of the epeiric water from the south, especially when it is realized that the whole region concerned had been thrown in to a state of disturbance by the Young-Kimmeridgian Movement. Nevertheless, the fact remains that there is no positive evidence to show that such a retreat of water was compensated by a transgressive movement in the neighbourhood of the respective areas.

On examining more clsoely the southern development of the Neocomian, one finds certain indications which suggest a minor oscillation within the Neocomian time. The succession of the events is best indicated on the eastern border of the Russian Platform where there was a shallow but elongated depression extending between Petchora on the north and Crimea on the south. A temporary passage between the Arctic and the southern waters was probably established in the early Valanginian time when the open water generally retreated northward. For this would be the most feasible, if not the only possible, way to account for the occurrence of *Aucella crassicolis*—a typical boreal form—in Balaclava, Crimea. The next stage, *i.e.* the Hauterivian, is entirely unrepresented throughout the length of the depression. Some time during the Barremian, the connection was again established enabling a fauna of *Simbirskite* to migrate southward. Thus in Crimea we find several species of *Simbirskite* occurring side by side with *Lytoceras* and *Phylloceras*.

A somewhat similar, though not quite so obvious, relation exists between the successive stages of the Neocomian formation in the Rhône Basin. There, the Valanginian attains a relatively restricted development with a fauna of *Phylloceras, Lytoceras, Duvalia, Pygope* etc., clearly of the Mediterranean type. In the next stage, the Hauterivian, the shallow water facies becomes more extensive with concomitant admission of North European species. For the most part of the Barremian, the deep water facies covers a much larger area. At this stage North European forms are again excluded from the basin, and the remains of the southern fauna play an important part in the formation of the deposit. From the beginning of the Aptian, the water again retreated, and the northern communication was once more established. This retreatal movement in the Rhône Basin is synchronized by the Lower Greensand invasion in southern England and northern France.

These two parallel instances suggest that the northerly retreat of the early Neocomian water probably continued up to the end of the Hauterivian stage; and then the water reversed the direction of its movement from the north to the south: that is, retreated from the north and expanded in the south, terminating at the end of the Barremian or the latest, the early part of the Aptian time.

That this late Barremian or early Aptian invasion in the south is not a local incident is indicated by the nature and distribution of the Urgonian Limestone which is so well developed in western Alps, in the Flysch Zone, southern Caucasus, and in Italy where it is the most constant horizon among the various stages of the Neocomian; and is often transgressive. In the

Gulf of Mixico area, the greatest inundation during the Neocomian took place in the Fredericksburg Stage which contains a fauna of ***Requienia, Monopleura, Radiolites*** etc. resembling that of the "Schrattenkalk" of the Urgonian [113c].

While it is generally recognizable that an equator-ward movement of the open water took place in the middle and lower latitudes during the later part of the Neocomian time, we must at the same time admit that this movement cannot be compared, in extent, with either the early Neocomian invasion in the higher, or the Cenomanian invasion in the middle and lower latitudes. As a whole, we may picture, if we take no account of the deformation of the lithosphere, that the oceanic surface in the Neocomian time is somewhat less oblate than in the late Jurassic or in the Cenomanian; for marine Neocomian formation is not only wide-spread in the Arctic area, but occurs in Padagonia, Graham Land, and in South Africa where it is known under the name of Uitenhage Beds. The Urgonian invasion would then probably mark a minor cycle of oscillation within the grander Neocom-Cenomanian cycle.

(b) Cenomanian Cycle

The Cenomanian Cycle started with a minor but general retreat of water towards the north. The retreat probably commenced from the later part of the Aptian, and continued during the Albian time. In the southern regions we find here and there the Aptian and Albian are partially represented by a break. This is clearly the case in the southern part of the Rhône Basin [52e]. In Savoy and probably western Jura, the Aptian is often either partly or entirely missing [52f]. In southern Spain, the Albian is known only to the east of Andalusia. In the Bavarian Sheet, Aptian is unrepresented; while the other stages ranging from Valanginian to Cenomanian are all present [130]. In West Africa, there is on the other hand a fairly extensive geosyncline, the "Angola Gulf" of professor Gregory, in which are found strata dating from the middle to the upper Albian times. Many more instances could be given, but since such instances could be equally well accounted for by the post-Urgonian or Austrian disturbance in the mobile zones, they afford no proof for a general movement of the open water.

More convincing is, however, the evidence that we find in the stable region of the Russian Platform. There, the Albian is restricted to the northern belt, namely, in Moscow, Vladimir and Simbirsk, but is absent from the southern part of the Platform; for instance, in Pologne, Podolia. Even in Crimea, the presence of Albian is doubtful. That this northerly retreat of the Albian water is not a local or regional phenomenon is indicated by the Gault invasion in England and by the temporary expansion of the Arctic water in N. America. The latter case has been graphically described by Schuchert who writes [114b]: "It was during the later Lower Cretaceous (Blairmore-Albian) that the Arctic Ocean began to spread south through the Rocky Mountain Geosyncline, but these marine waters seemingly did not extend south of the Peace River of Alberta, though fresh-water coal-bearing strata of about this time (Kootenai) occur southward through Alberta into Montana. Then the sea retreated northward." It may be noted that this retreat of the Arctic water from the north approximately corresponds to the expansion of Dakotan Sea in the south as the result of the Cenomanian transgression.

As was already noticed by Suess, the Cenomanian transgression which really persisted to the Turonian time, largely affected the southern part of the Northern Hemisphere. Vast areas in the high latitudes stood above marine water. In north-western Africa, to the south of the Saharan Atlas, the Cenomanian covers the plateaus of Tademait, Tinghert [124], Hamada el Homrah (in Tripoli), extending as far south as Gurara, Muidir and Issauan regions. In these areas the Cenomanian is distinctly transgressive, and the Albian only occurs here and there underneath it.

In Algeria and Tunisia, the transgressive Cenomanian consisting of marls and limestones often rests on the Jurassic particularly well shown in Seressu and Lehu, south of Tiaret, Province of Oran. The Albian generally rests conformably on the Aptian in the northern zone, but becomes transgressive on the northern border of the high plateaus in the province of Oran. The Turonian sometimes seems to be absent from northern Tunisia; but concordantly overlies the Cenomanian in the northern zone, and becomes transgressive towards Moroccan Meseta [52g]. Deposits ranging from Vraconnian to Turonian in age occupy considerable areas in Sudan [43] and Angola [15]. They are undoubtedly of marine origin, though probably largely formed in shallow water.

Typical Cenomanian is widely distributed over Upper and Lower Egypt in and immediately above the Nubian Sandstone [39]. The latter is a marginal deposit in the advancing Middle and Upper Cretaceous water. The Turonian seems to be rather poorly developed in Egypt as a whole; it is unknown in the Sinai District. Similar conditions appear to prevail in southeastern Arabia [26], Palestine and Syria [7].

Cenomanian transgression is again recognizable on the northern side of the Mediterranean, particularly in the western part of it. Thus Cenomanian with its typical fauna is well-developed in western Portugal, though, there, the transgrssion probably already started in the Albian time [16]. In southern Spain, Cenomanian is developed with its usual fauna, but the Albian is only known to the east of Andalusia.

In and around the Rhône Basin, the Cenomanian is now and then represented in its basal part by coarse sandstones which at times carry lignite indicating incipient transgression [48]. The Albian is often absent as in the neighbourhood of Gard and Ardèche, or slightly developed or represented by red sandstones.

Eastward, if we turn to the Savoy region and the western Jura [9], we find the Albian as well as the Cenomanian both transgressive. The latter presents a variable facies showing the approach of land.

It is true that in the eastern Alps and the eastern Iranian area, the Cenomanian together with the Albian and Turonian are often missing or poorly developed, e.g., in the Flysch Zone where the Cenomanian is only represented by the thin bedded Seewerkalk overlying a sandstone of Albian age. This absence of the Cenomanian in parts of the eastern Iranian areas would seem to be a face in favour of Haug's theory of compensation. Stille has however recently demonstrated that this break is rather to be attributed to the post-Neocomian and pre-Cenomianian or Austrian Movement which must have uplifted some of the synclinal areas. That such local uplift of the synclical areas is far from being adequate to compensate the immense flood that took place elsewhere is shown by further inundation. On the northern border of the Bavarian Sheet. the Cenomanian consisting of grey limestone, marls and conglomerate rests immediately on the Trias and Jurassic. In the western Florence region, in Reggio, South of Calabria, the Cenomaninan directly overlies a schist. In Transylvania the Cenomanian is well-developed, and rests on the Neocomian or schist [83]. In the Inner Zone of the Carpathian, Cenomanian marl overlaps the Jurassic. Marine Cenomanian is developed in the western part of the Bulgarian Plateau, between the Danube and Balkan, and is probably represented in Crimea by a chalk. In Podolia, southern Russia [125], Caucasus, it is represented by an argillaceous limestone overlying a glauconitic sandstone of Albian age. In the Transcaspian region (Manguychlak), Cenomanian shale overlies Albian sandstone and gypseous deposit [118]. In southern Persia (Luristan), both the Cenomanian and Turonian are represented by limestones [28]. In the Hazara district [78], Himalaya, Vraconnian or lower Cenomanian limestone overlies the Giumal sandstone. and the latter is overlain, in Spiti, by the Chikkim Limestone which is probably of Cenomanian age. The same Cenomanian horizon with characteristic *Acanthoceras* appears to have stretched not only into the Kampatsong-Tūna synclinal [53], on the southern border of the Tibetan plateau, but enters into composition of the upper part of the Utatur Group in Peninsular Inida where it either rests on gneiss or on continental beds of the Radjmahal Group [26]. Further south-east, marine Cenomanian is reported to occur in the Malay Peninsula (Arrakan), Java and Borneo (Kapua Basin).

The Cenomanian and Turonian are represented in North America by the Upper Dakota or Upper Washita, and possibly lower Benton. According to Schuchert, the Dakotan Sea which flooded the Rocky Mountain Geosynline between the Liard River on the north and northern New Mexico on the south in the course of the Lower Cretaceous time, began to spread southward in late Lower Cretaceous (Blairmore), and finally united with the expanding Mexican Water in the Benton time [114a].

Apart from the case of North America where existed a continuous trough extending from the Arctic-Mackenize region to the Gulf of Mexico and where the Rocky Mountain Geosynline was in an active state of growth, we find only two other areas in the Arctic where they were affected by the Cenomanian transgression. The first is a geosynline stretching across middle Greenland with a Caledonian or Appalachian trend. The second is the Anadyr Basin in north-eastern Siberia. Of the first area, little is known; in the second, there occurs an enormous thickness of Cretaceous deposit which is estimated by Polevoi at 4690 m. [87d]. The middle part of this series which may yet prove to be of uppermost Albian age consists of sandstones and sandy clays, and contains *Helioceras venustum. Stoliczkaia disper, Lytoceras timotheanum* showing an affinity with the fauna of the Utatar Group of India. The allegad presence of Cenomanian in the lower Yenissei based on isolated occurrence of *Microbacia coronula* cannot yet be considered as an established fact. Into these depressions or actively subsiding areas we may expect marine invasion at any time. Such local invasions which may well have been caused through the depression of the land surface cannot be taken as an argument against the general expansion of the Cenomanian water in the south: for the latter is by far the more sweeping and widespread.

(c) Senonian Cycle

During the Senonian time, the open water in the Northern Hemisphere seems to have maintained the general tendency of advancing southward, as for example, indicated by the gradual rise of the Nubian sandstone to a higher horizon towards southern Egypt, the coutinued submergence of the Gulf of Mexico area and the persistent southward shrinking of the Coloradoan Sea. In spite of this general tendency, it is possible to recognize a temporal northerly retreat of the open water in lower Senonian time, which is sufficiently general as to mark the beginning of an independent, though subordinate, cycle of oscillation.

This Lower Senonian retreat is apparently of a more decisive character than the Albian retreat; for considerable areas in the Arctic were inundated in the Santonian and Campanian times. Thus, on the River Sosva, below the Manya (between the latitudes 60° and 65° N.), there occurs a glauconitic shale with *Baculites* and *Scaphites* [40]. On the River Ayat, a left tributary to the Tobol, Kransnopolski has found, at 53° N. (30 to 55 km. below Nikolaevski), a fauna of Santonian and Campanian age [49] consisting of *Belemnitella lanceolata*, *Exogyra decustata*, *E. auricularis*, *Ostrea vesicularis* etc. In the southern Ural, the *Belemnitella lanceolata* bearing formation horizontally overlies eroded older rocks.

In eastern Siberia, marine Senonian, and probably for the most part Lower Senonian, occurs in the Tingenei Mountain, on the northern coast of the Ochotsk Sea [110] and on the Tigil River in Kamtchaka. In Sachalin, the stratigraphical relation is quite clear and striking. According to Kryshtofovitch [65], the Cretaceous formation of the Sachalin Island can be generally classified into three series. The Lower or the Aino Series is of continental origin, and bears plant fossils, correlatable with the Kome Series of Greenland, and is therefore to be referred to the Upper Neocomian. The Middle or the Gilyak Series is a coal-bearing formation yielding Cenomanian and lower Turonian plants, and is regarded as an equivalent of the Athanee Series of Greenland. The Upper or the Orotschon Series consists of light grey and green, glauconitic, calcareous sandstone with marls and concretions. A rich fauna consisting of *Phylloceras velledae*, *Pachydisous peramplus*, *Gaudriceras sacua*, *Tetragonites timotheanus*, *Puzosia planulata*, *Inoceramus elegans*, *I. orientalis*, *I. lobiatus*, *Helcion giganteus* etc., occurs in the upper part of the series. Below and above this fraunal zone, there occurs a flora which, according to Kryshtofovitch, is comparable with that of the Patut Series of Greenland. The age is then essentially Lower Senonian and perhaps partly Upper Turonian. The fauna is a strange mixture of southern emigrants and Arctic forms. The ammonites constitute the very same fauna of that of the False Bay Formation of Zululand, S. Africa, and that of the Utatur Group of Peninsular India. *Inoceramus lobiatus* is a form widely distributed in the Colorado formation of North America, and abounds in the upper part of the Utatur Group. The whole fauna would seem rather to suggest a Turonian Age. Sokolow [111] who examined the fauna, refers, however, the ammonites to the Emscher and the Inoceramuses to the three horizons, particularly the uppermost one, of the Campanian. This series is covered by a conglomerate which probably belongs to the Laramie or early Tertiary.

From our point of view, it is however a matter of no great consequence whether this deposit in a geosyncline on the continental border be of Turonian or Lower Senonian age. The most reliable indication of an early Senonian invasion in the north is rather to be found in the flood on the eastern side of the Ural, making a fairly large inland sea that divided the Eurasian continent in the way as the Coloradoan Sea did to the North American continent at approximately the same time.

If we turn to southern regions of the Northern Hemisphere, we find the condition more or less reversed. The Lower Senonian is sometimes absent or poorly developed, while the upper Senonian generally effects a transgression of a most sweeping and decisive nature.

A number of instances will suffice to establish the case. In southern Spain, the Maestrichtian and Danian are both well developed while the presence of the lower stages of the Senonian is highly problematic [52h]. On the southern border of the Rhône Basin, to the south of Languedoc, the Danian directly overlies the Neocomian; and in Basse-Provence, the successive stages of the Lower Senonian with a basal layer of laterite overlaps northward. In Savoy, the Santonian and Campanian are often missing, and only poorly developed to the south of Dévoluy, whereas the Maestrichtian is decidedly transgressive.

Tunisia and Algeria apparently remained to be a part of a Basin in which sedimentation proceeded uninterruptedly since early Cretaceous time. To the south of the Saharan Atlas, the Senonian formation is often denuded away. It is therefore difficult to make out the stratigraphical relation between its successive stages. Cretaceous formation is reported to occur extensively in western Africa [73]. From the fossile obtained from the Adar-dutchi and other districts, Sudan, it appears that at least a part of that formation represents a marine invasion in the Maestrichtian or Danian time. In Egypt, Syria, Palestine and south-eastern Arabia, the Maestrichtian or Danian is generally represented by a marine fossiliferous deposit, and shows a marked tendency, in Egypt, to transgress southward [84]. The Santonian and Companian are either absent, or partly or wholly represented by continental deposit.

In the eastern Alps, the various shallow, brackish or fresh water facies of the Lower Senonian are known under the names of Vienna Sandstone, Gosau Series etc. They are generally overlain by the Maestrichtian with a marine fauna. The varied nature and peculiar distribution of the Gosau and its equivalent in the eastern Alpine region together with the fact that they often rest on much older rocks, e. g. Trias or Jurassic, prove that they were not formed in a quietly advancing or receding water, but deposited in a region where some tectonic disturbance had taken place. Stratgraphical data obtained from such highly disturbed areas can afford no evidence for the general displacement of sea-level.

Further east, in Balkan [126], Dobrogea, Carpathian [100,83] Crimea [17], Caucasus [1], Transcaspian (Manguychlak) [118], southern Persia [28], Baluchistan [86], the Lower Senonian is in general either partly or entirely missing, whereas the Cenoman-Turonian and the Maestrichtian are both well-developed. The latter often effects even a more sweeping transgression than the former.

In the Salt Range, nothing is definitely known of the development of the Lower Senonian. It is probably absent. The Maestrichtian attains, however, a fairly extensive development on the Tibetan border; and in Sind it is represented by the Hippurite Limestone. In Peninsular India, Lower Senonian is represented by the Trichinopoly Series, and the Upper Senonian by the Ariyalur and Niniyur Stages [131]. The former is only developed in the Trichinopoly area where it overlies the Utatur Group; but the latter attains a greater extension, being present in the Trichinopoly as well as the Pondicherri areas [63]. In this last-named district, apparently it rests on much older rocks.

The Maestrichtian transgression in the Eastern Hemisphere is probably equivalent to the Pierre or Bearpaw or the Ripley expansion of the Coloradoan and the Mexican waters. Large areas in Central Mexico, in the Great Antills and along the Gulf-border and the Atlantic Coast of the United States were then under marine water which was in free communication with the Coloradoan Sea [113d, 114c].

The whole history of oceanic oscillation in the Northern Hemisphere during the Cretaceous time may be briefly summarized as follows:

With the opening of the Neocomian epoch, there was a decisive displacement of marine water to the north, followed by a minor movement to the south, which ended in the Urgonian transgression; then came a minor movement to the north during the Albian time. The next sweeping movement to the south, namely the Cenomanian transgression, which really lasted till, at all events, early Turonian, was followed by the temporary Lower Senonian retreat to the north. Finally there occurred the Upper Senonian transgression towards the south, which drowned even areas that remained land during the Cenomanian transgression.

Now from the extensive discussion of H. Stille we understand that there were two episodes of earth-movement during the Cretaceous. The first is the Austrian Movement which Stille places at the end of or partly in the Albian time. But from the fact that local rearrangement of land and water had already begun in late Aptain time, it would seem more appropriate to place this movement either within or just before the Albian time. In England (Dorset and Wiltshire) there is evidence to show that the Gault was laid upon gently folded and slightly eroded Lower Greensand. This would determine the Austrian Movement as pre-Albian. The second is the Subhercynian Movement which occurred between the Turonian and the Senonian. Besides these two movements there are of course the Young-Kimmerian Movement with which opened the Cretaceous Period, and the Laramide Movement with which this period was closed.

It is therefore evident that the correlation of these events entirely conforms with the general rule that each episode of wide-spread tectonic movement is preceded by a southward, and followed by a northward movement of the open water.

D. PALÆOGENE.

On approaching the mid-Tertiary movements, crustal strain became ever more intense. Continental blocks were, as a whole, raised high through continued compression; and minor disturbances consecutively broke out over large and small areas without being restricted to a definite epoch. So incessant and wide-spread were these regional movements that the temporal relation between the transgressions and the tectonic movements during the Palæogene Period is no longer so clear as in the Jurassic and the Cretaceous. Nevertheless, two stages—the Lutetian and the Tongrian—of broad expansion of the epicontinental waters in the middle and low latitudes are definitely recognizable. The former foreshadowed the Pyrenees Movement and the latter the great Alpine-Himalayan Revolution.

(a) Lutetian Cycle.

The notion of a geological cycle as developed in the present paper embodies a sweeping movement of the oceanic water first away from, and then toward, the equator, or more briefly a single oscillation of the form of the oceanic surface. The terms, Palæocene and Eocene in their accepted senses do not, taken individually, seem to conform with such a notion. There may have been minor oscillations within each of these periods; but the first major one was not completed until the Lutetian advance.

We have already seen that after the Maestrichtian transgression in the low latitudes, there occurred the Laramide Movement. If the general rule governing marine transgression holds in this particular case, we ought to find evidence somewhere in the northern region for the expansion of Arctic water during or at least in the early part of the Palæocene time. Such evidence is available, though not absolutely conclusive.

According to Wyssozky [50] and Obrutschew, the early Tertiary formation is represented in western Siberia by a rather coarse grained, grey-green sandstone, containing nodules of glauconite, a fauna of *Pholadomya, Cyprina, Ostrea* and teeth of *Lamna.* This formation has been assigned to the Eocene; but none of these organic forms assures that age, nor are we able, on the strength of this meagre fauna, to exclude the possibility of its being a Palæocene representative. On the contrary, it is reported that this very formation sometimes (as in the valley of the Ayat, a tributary to the upper Tobol) grades down, without any break, into sandy clay with an Upper Cretaceous fauna. In the absence of decisive evidence, we cannot then positively deny the presence of marine Palæocene in western Siberia.

In the "Turgai Strait" and to the south of the Kirghiz Steppe, glauconitic sands and sandstones of Palæocene age are reported to occur [101, 66]. These are overlain by a fairly thick series of marine sandstones and clays of Eocene age [102].

Based on these data and other isolated outcrops of early Tertiary deposits along the Tobol, the Ob, the Irtysch Valley and near Semipalatinsk, Obrutschew [87e] draws the conclusion that in the early Tertiary times there existed two seas that covered the northern and southern areas of western Siberia, being connected, on the west, by a longitudinal, broad water way—the "Turgai Strait". The Northern Sea is further divided by a strip of land which stretches in between latitudes 54° and 60° N., and runs in a E. S. E. direction until it joins Kusnezki Alatau and Salair. Thus we are enabled to see the probable extent of marine water that covered northern Asia in early Tertiary times.

Of the early Tertiary geography of N. E. Siberia and Arctic North America, very little is as yet known. In all probability, the whole of these areas were raised to such an altitude through the Laramide uplift as to forbid the invasion of marine water.

As to north-western Europe, the circumstances are far more favourable for our investigation. For there existed the Anglo-Franco-Belgian basin on the one hand and the Russo-Baltic depression on the other. The former included the Netherland area and the German coastal districts. The latter extended from the eastern border of the Anglo-Franco-Belgian basin eastward across the Russo-Baltic Plains to the northern border of the Turgai depression on the north. In the lower Palæocene time, only restricted areas in these depressions retained some marine water; and only in those restricted areas such as Mons, Belgium, do we find deposits in engulfed water. These form the peculiar "Ciply Tufa" and the strata of the Montian Stage. It has been emphatically pointed out by A. W. Grabau [46] that the Montian formation of the Franco-Belgian area changes its character upward from marine to fresh water deposits. And at certian localities its surface presents markings of a pre-Thanetian erosion. Then there followed a more sweeping transgression in the middle Palæocene time. This resulted in the complete flooding of the London-Parisian Basin and the Russo-Baltic Bay. With this invasion there arrived the *Cyprina*-fauna which is undoubtedly of boreal origin. The Palæocene deposits found in Cape Dalton, Greenland, were probably formed during this period of flood [108].

These facts furnish us strong evidence for a continued regression of marine water towards the north during the lower and middle Palæocene times. To appreciate the evidential value of these facts, it must be remembered that the Anglo-Franco-Belgian Basin together with the Russo-Baltic Bay was only connected with the open water on the north in those times. Consequently, during the early stage of the retreatal movement of marine water toward the north the water in the embavment (which is situated between 50° to 60° N.) would be temporarily drained away. Further movement of the open water towards the north necessarily resulted in the expansion of the boreal sea which then flooded the embayment. This gave rise to the Thanetian transgression.

As to the southern basins, the conditions are more or less reversed. Along the northern zone of the Pyrenees, and the southern border of the Aturian Basin (Biarritz), the Palæocene is wholly wanting, and the upper Lutetian with *Nummulites lævigatus, N. biarritzensis, N. aturicus, Orthophragmina stella,* etc. and a basal conglomerate, rests at once upon the Chalk. The whole series ranging from upper Lutetian up to Rupelian is estimated at 1500 m. in thickness, of which the most part is of marine origin [29]. Tracing eastward to the east of Bayonne, marine Lower Lutetian, with *Alveolina elongata, Nummulina murchisoni, Orthophragmina archiaci,* etc. is developed underneath the Upper Lutetian, but the Palæocene is still unrepresented. In the Saint Sever district [58], only the uppermost stage of the Palæocene is represented by a sandy and galuconitic limestone with *Nummulites planulatus* followed upward by limestones of Lutetian age. In the region of Pau and High Pyrenees, marine Lutetian is discordantly underlain by the Upper Cretaceous, and "concordantly" overlain by the "Poudingue de Palassou" which latter attains a powerful development in Haute-Garonne and Little Pyrenees [72], and affords unmistakable evidence for a post-Lutetian movement.

Throughout the Sub-Pyreneean Geosynline, only in that limited area which extends over Haute-Garonne, Foix, Corbières, Aude and up to the Herault dirtrict, Palæocene formation is here and there developed. And in most cases, the deposits are of brackish water, lacustrine or even partly continental origin. The overlying Lutetian is however generally marine.

In the Southern zone of the Pyrenees, for instance, in the provinces of Huesca and Lerida, the Lutetian is sometimes represented by marls and sometimes by Limestones, but the Palæocene is unknown, and in all probability, entirely wanting [18].

Palæocene is again absent from the western and northern part of the Alpine Geosyncline. In these areas it is often the higher terms of the Eocene, the Auversian and Priabonian, that overlie the older formations. The Lutetian with *Nummulites millecaput*, sometimes appears in the axial zone of the geosyncline, such as in the axial zone of the Delphino-Provincial Alps the inner zone of the Savoy Alps, the eastern part of the antochitonous zone of Swiss Alps, and parts of the Helvetic and the Prealpine sheets where it is known as "Wild-flysch" [10]. Although the stratigraphical relation between the Lutetian and the older formations is often rendered obscure by repeated over-thrusts, there are instances which clearly demonstrate, as in the Maritime Alps and Savoy, the transgression of the Lutetian upon the Cretaceous, Jurassic and even Trias. Further east, the Lutetian with a rich fauna of Foraminifera, echinoids, and molluscs is developed in the external border of the so-called Flysch Zone, and extends to as far as the west of Salzburg [41].

In eastern Alps, the highest stage of the Palæocene is occasionally represented by a relatively thin marine formation, e. g. in Carinthia Trentin and Vicentin [52]. In the last named locality the Londinian is represented by the "Spilecco Series" resting at once upon the Maestrichtian Scaglia. These developments are of restricted distribution, and are generally overlapped by the Lutetian. Further evidence of the Lutetian transgression is found in Istria, Dalmatia [120], Albania, southern Tyral, eastern Bosnia, western Serbia [88], northern and central Apennine, Calabria, Sicily [19], Syria, Transcaucasia [36], Asia Minor [121] and Persia [12].

In the Subbeskide and Beskide Zones of the outer Carpathian, Palæocene strata are unknown, but the Eocene with *Orthophragmina. Lithothaminium* and *Nummulites* attains a considerable development [128]. A part of this Eocene formation probably belongs to the Lutetian as is suggested by the occurrence of *Nummulites aturicus* in the Moldavia district. In Eastern Balkan and Crimea, marine Lutetian with a characteristic fauna rests at once upon the Cretaceous, the Palæocene being absent.

In Central Hungary and Transylvania, the Palæocene is sometimes represented by fluvio-lacustrine, continental, and rarely fluvio-marine deposits. The Lutetian is however generally marine, and often shows signs of incipient transgression [30].

In Egypt, the Palæocene is represented by the Libyan Series which concordantly overlies the upper Cretaceous. This series yields, in its lower part (marls and limestones about 200 m. thick), numerous Foraminifera such as *Operculina libyca, Assilina minima, Nummulites deserti etc.*, and in its upper part, again a foraminiferal fauna showing Lutetian affinity. Among them there are *Fabularia zitteli, Alveolina oblonga, Orbitolites complanatus, Nummulites biarritzensis.* Overlying the Libyan is the Moqattam Series, the lower part of which definitely proves, with a fauna of *Nummulites gizehensis, Conoclypeus corroideus* and *Velates schmiedelianus*, to be of Lutetian age [8,89].

In the Atlas region, the Palæocene is sometimes missing and the Lutetian transgresses upon the older rocks (zone of the Tell and the axial zone of the Atlas); and sometimes the Palæocene concordantly overlies the upper Cretaceous, the Lutetian being either partially or wholly denuded away (northern zone of the High Plateaux and the Saharan Atlas) [57]. In the latter case, there occurs, as a rule, a phosphatic bed, the Gafsa Bed, and its equivalents representing the Middle Palæocene. This deposit, as shown by Grabau [47], indicates a period of emergence which corresponds, in point of time, to the Thanetian transgression in the north.

Marine Lutetian appears to occupy fairly extensive areas in Somaliland [85], ex-German East Africa [122] and Madagascar [31]. In these areas no marine Palæocene is yet known, and probably does not occur.

The Palæocene is represented in western India by the Ranikot Series of the Sind district. The lower part of this formation consists of sandstones and clays of fluviatile origin, and has a thickness of 300-450 m. The upper part of the same series consists of marine limestones intercalated with sandstones and shales, and attains a thickness of 210-240 m. The uppermost part of this series has yielded *Operculina, Assilina micella* and *Nummulites planulatus*. These indicate the presence of Londinian [132]. The Ranikot Series is overlain by the Laki and Khirthar Series which contain typical Lutetian forms; namely *Nummulites atacicus, N. irregularies, Assilina granulosa, Operculina orbitoides, Alveolina*, in the Laki Series, and *N. Lævigatus, N. aturicus, N. gizehensis, N. millecaput, Assilina exponens* in the Khirthar Series. These strata attain a much wider distribution than does the underlying Ranikot. They extend, for instance, into the interior of Baluchistan, the vicinity of Lhasa and to the south of the Plain of the Indus where the Ranikot is absent. Further south, Lutetian appears to occur in the Cutch, Gujarat, Travancore districts on the western side of the peninsula [134].

The presence of *Nummulites biarritzensis* in south eastern Borneo [32] and *Assilina spira* in Java [133] points to the free communication between the Mediterranean Basin and the Indo-Pacific water in early Eocene time. Consequently it affords corroborating evidence for a general expansion of the southern waters in the Lutetian time.

In north America, marine Palæogene formations are largely restricted to the Gulf of Mexico region and along the coastal range of California. The Palæocene formation is only slightly developed in these regions. It is probably represented by the Martinez Formation of central California and the Midwayan of the Gulf region. The Lutetian with the characteristic species *Venericardia planicosta* not only attains a much wider distribution in California and the Gulf region [33], but is present in Maryland [20] southern Carolina [21] and Mexico.

Thus we see that in the southern regions of the Northern Hemisphere, the Palæocene is often represented by a break. When the Palæocene strata are developed at all, they were either formed in isolated basins that existed as relics of the Cretaceous sea, or formed actually in retreating water. Whereas in the Lutetian the evidence for a general expansion of the epicontinental sea is everywhere manifest. This universal flood in the south may have started already in late Londinian time; for in a number of areas the Lutetian concordantly follows the late Palæocene deposit of marine origin. It is true that at about the same time the Anglo-Parisian Basin and the Turgai Geosyncline—both of which ought to be regarded as southern extensions of the northern sea—also showed some tendency of submergence, but eleswhere in the north no signs of a general Lutetian advance are to be found. They are therefore to be more properly attributed to the subsidence of the geosyncline as a result of tectonic evolution than to a general elevation of sea-level in the north. Moreover the expansion of water in these southern extensions of the northern sea appears to be restricted to their southern part, that is, to the south-western margin in the case of the Anglo-Parisian Basin, and to the Dniepr and Donetz areas in the case of the Turgai Geosyncline. Still more significant is the fact that in the Anglo-Parisian Basin the transgression did not reach its climax until the middle or upper Lutetian times (this is also the case in the Aquitanian Basin), and in the Turgai Geosyncline the transgression continued throughout the Auversian and Priabonian epochs when the "post-Lutetian" or Pyrenees movement had been already well under its way.

(b) Tongrian Cycle.

Following the Pyrenees Movement, the southern waters began to retreat. That they retreated northward is best shown in Egypt by the progressive shifting of the higher stages of the Eocene towards the north, and by the expansion of the Middle and Upper Eocene water in the Turgai Geosyncline. In the Atlas region the higher stages of the Eocene as well as the Tongrian are either partly or completely wanting, or the higher Eocene is represented by a hiatus, while the Tongrian is transgressive [52].

Throughout the northern Mediterranian region, the invasion of the Tongrian water is a fairly universal phenomenon, though perhaps it has hardly reached the same extent as the Lutetian Sea. In the Sub-Pyrenees Basin marine Lower and Middle Oligocene with *Nummulites* (*N. intermedius-fichteli*) and *Operculina* (*O. ammonea, O. complantata*) succeeds a thick series of Eocene. In the famous Biarritz district which is probably situated in the central part of the Basin, there is hardly any sign to show the transgression of the Oligocene water: but if we trace to the districts of Gass [13], and Gamarde, the Priabonian disappears, the Rupelian or Middle Oligecene rests directly upon the Auversian.

All along the outer zone of the Alpine Geosyncline, evidence for a Tongrian transgression is found in the Barreme district (Basse-Alps) [11] on the external border of the Bauge massif (Savoy) [34], in the tract between Gemmi and the Surenen Pass (Swiss Alps) [10], and in Bavaria where it is known as the Lower Marine Mollasse.

In the eastern Alpine and the Apennine regions evidence for a Tongrian transgression is likewise manifest. Thus in the Provinces of Vérone and Vicence the Lattorfian, or lower Oligocene overlies, with a basal conglomerate, the Priabonian [90]. Near the hills of Turin in Ligulia [103], the Oligocene is characterized by a mixed fauna of *Nummulites* and *Lepidocyclina*. The presence of these forms in one and the same locality clearly indicates the confluence of the Pacific and the Mediterranean waters. To the west of the Scrivia Valley this Oligocene formation directly overlies the Permian. As far as the Oligocene is concerned, similar stratigraphical relation holds in southern Italy and Sicily.

Turning now to the northern border of the Dinarides, we find in Styria, Carinthia and other localities the Lattorfian transgressing upon the older rocks, the Eocene being absent [127]. Further east, the Tongrian is represented in northern Carpathian (Pausram) by a marine formation of argillaceous character, and in the outer zone of southern Carpathian by a conglomerate with small *Nummulites* representing, in all probability, incipient transgression. In the Balkans (near Burgas), and Crimea (Alma Valley), the presence of marine Oligocene has been demonstrated, though its stratigraphical position is not yet definitely known

The areas so far referred to, belong to the Mediterranean Basin or its extension. There existed at the same time a second basin in Europe which runs more or less parallel to the Mediterranean Basin, but almost completely separated from it by a narrow strip of land. This second basin was likewise flooded by the Tongrian water covering Belgium, northern Germany, Central Hungary and finally joining the Turgai Geosyncline in its southern end. The fauna inhabiting this sea is eminently of the northern type and largely of shallow water habits. Since we cannot readily attribute this body of water either to the north or to the south, and since this depression is of "posthume" nature as pointed out by Haug, the presence of this sea across Middle Europe does not then affect our argument, unless the predominant influence of the northern fauna that flourished in this body of water is taken to be indicative of the inundation of the boreal water.

Marine Oligocene is only of restricted occurrence in Asia. The Nari Series [134] of the Nari Valley in western India was undoubtedly formed in an arm of the Indian Ocean, and overlaps the older formations. The fact that *Lepidocynclina* occurs in this series shows that free communication with the Pacific must have been maintained through the Malay Archipelago. The occurrence of Middle and Upper Oligocene in Borneo suggests the probable path of communication [32].

On the other side of the globe, marine Oligocene with *Lepidocyclina* attains a fairly extensive distribution in the Gulf area. It is known, for instance, in Alabama and Florida under the name of Vicksburgian Series [21]. In the Great Antilles, too, the same formation with *Lepidocyclina mantelli* assumes an important development. There seems little doubt that a general elevation, in the Oligocene time, of sea-level took place along the southern border of the North American Continent and in the Gulf of Mexico area at large. This led to the submergence of some of the detached land-masses in the Gulf region.

Looking now far into the north, we find only two adjacent areas in the northern part of the Eurasian Continent that were affected by the Tongrian cycle of sedimentation. The one is located in the northern part of western Siberia, and stretches along the eastern foot of the Ural and the northern border of the Kirghitz Steppe. The other is known as the "Turgai Strait" which is situated to the east of the southern Ural with a meridional trend, and joins the "Southern Sea" which spreads from the northern border of the present Aral Sea eastward to the south of the "Islands of the Kirghitz Steppe".

In the northern area of western Siberia, the lowest Palæogene formation so far reported consists of a coarse, greenish-grey sandstone with *Cyprina*, *Ostrea* and teeth of *Lamna*. This formation, as has been already suggested, may belong to the Palæocene or Lower Eocene. Overlying this formation is a sandstone with siliceous earth yielding impressions of *Arca* and *Modiola* and remains of *Botroclorium spasskii*. It fills up the valley and covers the top of the low heights in the Kirghitz Steppe, and transgresses upon the eroded surface of the Mesozoic and cyrstalline rocks in the flank of the Ural Mountains [78e]. This formation undoubtedly represents the time of maximum transgression during the Palæogene Period. Certainly it does not belong to the Oligocene, nor is it likely to be a Lutetian representative. Its logical position is then Middle or Upper Eocene. The latter is more probably the case if it merges into the overlying Oligocene. We have therefore some evidence for the expansion of the northern sea during the time when the southern seas retreated.

The Oligocene as developed in the same area, consists of clays with much gypsum and banks of ferruginous sandstone which latter yields an unmistakable Oligocene fauna including scales of *Meletta*. That the whole of this formation was deposited in a retreating water is shown by the abundant inclusion of gypsum and by its actual recession at higher horizons from the flank of the Ural. This merges upward into variegated clays and sandstones with coal smuts and plant remains showing the final disappearance of marine water.

Here again we have positive evidence for a regression of marine water during the time when the Tongrian transgression took place in the south.

In the Turgai Strait and in the the so-called Southern Sea of western Siberia, the stratigraphical relation is not quite so clear as in the northern area, There, both the Eocene and the Oligocene (Lattorfian) appear to have been developed. They are both marine, but the occurrence of gypsum in the coarse Oligocene sandstone and clay would seem to suggest, as in the northern area the contraction of marine water during that time.

In spite of the regional tectonic disturbance that must have been in progress over the more mobile continental areas on approaching the main phase of the Alpine Revolution, the stratigraphical evidence is, as a whole, favourable for the interpretation that in the course of the later Eocene times there occurred temporarily a general retreat of marine water towards the north as the result of the Pyrenees Movement; then followed a southward transgression—the Tongrian invasion—which foreshadowed the arrival of the grandiose Alpine uplift.

E. Quaternary Marine Invasion from the Arctic.

From the later part of the Oligocene and throughout the Miocene and Pliocene times, all the continental blocks were thrown into such a state of tectonic disturbance that the movement of the sea water in and out of the various subsiding or up-rising areas is no longer fit for the discussion from our point of view. The fact that demands special notice is the extensive invasion of the Arctic water over northern Siberia directly following the cessation of the great upheaval.

From the Ob Bay eastward to the mouth of the Chatanga, all along the Arctic coast, the invading water made its way land-ward to a greater or lesser extent. Along the Valley of the Yenissei it reached as far south as the latitude of 67° N., and in the valley of the Vilui, to the latitude of 62° N. In the New Siberia Islands, along the coasts of the Bering Strait, the Ochotsk Sea, the Ussuri Area and in the Sachalin Island, Quaternary deposits with typical boreal fauna such as *Astarte, Yoldia, Fusus, Mya, Tellina* etc., are scattered everywhere. The largest area affected is however situated in the north-western part of Siberia. The thickness of the deposit which usually consists of clays and clayey sands, sometimes reaches two or three scores of feet and sometimes thinner. Obviously, parts of the original sediment have been completely eroded.

Two different stages of transgression have been recognized. The first took place at the beginning of the quaternary, and affected the Yenissei and the Vilui Valleys. The second occurred in the post-glacial time or some interglacial period. It has affected the Taimyr Country, the New Siberia Islands, and the Anadyr Basin. This second stage of transgression reaches a much smaller extent than does the early Quaternary one, and may therefore be merely due to the melting of the ice sheets as the result of the prevalence of a less severe climate [87f].

Another Arctic invasion on an extensive scale during the Quaternary times is found in the Baltic Basin and its adjoinning areas. This sheet of marine water, known as the "Yoldia Sea", was connected with the White Sea in the north and spread over large parts of Finno-Scandinavia on the south. It is quite probable that the invading water into this area had, to some extent, taken advantage of the slow, isostatic adjustment on the part of the land-mass, but it appears to be equally probable that this was not the only cause for such an extensive marine transgression. The latter argument is all the more convincing when it is remembered that northern Siberia had already been under an extensive sheet of marine water before the culmination of the Ice Age.

In the southern regions, the land surface had essentially assumed its present form. Only small areas on the margin of the present Mediterranean were invaded by marine water. The Aralo-Caspian Sea perhaps spread to a considerable extent. But it was not so extensive as in the Neogene Period, and was no longer in communication with the Black Sea.

We may therefore conclude that during the Quaternary Period the Open water was to an appreciable extent displaced to the north suggesting that the oceanic figure was less oblate than in the time when the Alpine-Himalayan and other associated movements were about to break out.

III. Summary

The chronological relation between the dominant phases of marine transgression in the Northern Hemisphere and the important tectonic movements during post-Palæozoic times may now be summarized in a tabular form as follows:—

(Note—Those tectonic terms that are marked with an asterisk (*) are due to H. Stille. Their structural significance is fully discussed by the same author in his 'Grundfragen der Vergleichender Tektonik.')

Epochs	Characteristic facies of transgressive product.		Important tectonic movements or their representative phases.
	North	South	
			Late Palæozoic and Pre-Triassic Movement
Scythian	Shales, sandstones and conglomerates in N. E. Siberia with marine fauna;? Thaynes Limestone in N. America.		
Virglorian-Làdinian		Muschelkalk, Wettersteinkalk and Ramsau Dolomite in S. E. Europe; Muschelkalk in Carpathian, Crimea and S. W. China	
Carnian	Shales and Limestones in N. E. Siberia; Chitistone Formation in Alaska.		Mid-Triaisic Movement?
Norian		Limestones and dolomites in Alpine-Himalayan Geosynclines and their adjoining areas.	Old Kimmerian Movement*
Middle Lias	Marine sediment between Chatanga and Lena		
Aalenian		Rosso Ammonitico Limestone in S. Europe and N. Africa; Kioto Limestone (Tagling Stage) in Himalayan Geosyncline: Hardgrave Sandistone in N. Calfornia and marine clay slates in Gulf Region	Post Liassic Movement

Epoch	Characteristic facies of transgressive product.		Important tectonic movements or their representative phases.
	North	South	
Callovian-Oxfordian	Chiefly marine clays and shales occupying large areas in the Arctic Region of Eurasia and Greenland; upper Enochkin and Naknek Formations in Alaska; Fernie shale in British Columbia; Twin-Creek Formtion in Wyoming	Limestones in S. E. Europe and S. W. Asia. (transgressive?)	Post-Liassic Movement.
Argovian. Kimmeridgian	Kimmeridgian sandy clay in N. Ural and King Wilhelm land. (transgressive?)	Argovian Lime-Stone and Aptychus Formation in Mediterranean region and Eastern Alps; marine Kimmeridgian in Western Alps, S. W. Asia and Mexico; Tendaguru Series in E. Africa; Katrol and? Tal Series in India.	Young Kimmerian* Movement, (1st phase).
Lower Portlandian (Bononian)	Volgian in the Arctic.		
Upper Portlandian (Aquilonian)	Volgian in the Volga valley.	Tithonian in the Alpine Geosyncline;? Spiti Shale in the Himalayan Geosyncline; marine Portlandian in western Cuba, Mexico and Texas.	Young Kimmerian* Movement, (2nd phase).
Berrias-Valanginian	Marine sands and clays in the Arctic regions of Eurasia and Greenland; Anaktuvuk Series in Alaska; Knoxville in N. America.		

Epoch	Characteristic facies of transgressive product.		Important tectonic movements or their representative phases.
	North	South	
Barremian-Hptian		Urgonian Limestone in the Mediterranean Region; Parh Limestone in Baluchistan; Fredericksburg in the Mexican Gulf Region.	Austrian Movement.*
Albian	Gault in England; marine deposit in northern part of the Russian platform and (?) Anadyr Basin; Blairmore in N. America.	Local transgressive product in Oran, Western Portugal and Savoy.	
Cenoman-Turonian	Marine deposit in middle Greenland. (transgressive?)	Marine sediments occupying large areas in N. and W. Africa, W. Alps, E. Europe, S. W. Asia, S. Persia; Lower Utatur Group in Peninsulár India, and the Upper Dakotan Group in N. America.	Subhercynian* Movement.
Lower Senonian	Glauconitic shale and sandstones in N. and N. E. Siberia.		
Mæstrichtian-Danian		Marine deposits in Alpine Geosyncline N. Africa, Egypt, S. E. Europe, S. W. Asia, S. Persia Baluchistan; Hippurites and Chikkim Limestones in N. India; Ariyalur and Nininyur Series in Peninsular India; Pierre or Ripley in N. America.	Laramide Movement.

Epoch	Characteristic facies of transgressive product.		Important tectonic movements or their representative phases.
	North	South	
Palæocene	Glauconitic sands in N. W. Siberia; Thanetian in Russo-Baltic Bay.		Laramide Movement
Lutetian		Marine sediment in Alpine Geosyncline, S. E. Europe, Asia-Minor, Persia; Moqattam Series in Egypt; Laki in N. India and Baluchistan; Venericardia Formation in N. America.	
Auversian-Priabonian	Marine sandstone to the east of N. Ural and Kirghitz Steppe.		Pyrenees Movement.
Tongrian		Marine sediment in parts of Mediterranean Basin, N. Carpathian; Nari Series in India; Lepidocyclina Formation or Vicksburgian Series in the region of Gulf of Mexico.	
			Mid and Late Tertiary Movements.
Early Quaternary	Clay and Clayey sands covering large areas in N. W. Siberia and N. Europe.		

It will be noticed in the above table that in the columns under the heading of 'characteristic facies of transgressive product' are entered only some of those formations that are proved to be transgressive either by their lithological character and lateral extention or their actual superposition on much older rocks. Those that were formed in preexisting depressions or residual waters such as the Otoceras Limestone in the Himalayan Geosyncline, early Liassic deposits in the Mediterranean Basin, early Neocomian formations In the Alpine Himalayan Geosynclines, the Libyan Series in Egypt, the Ranikot Series in India etc. seldom show any sign of transgression, and therefore are not to be attributed to the same category.

In some cases, transgression appears to have been simultaneously effected both in the north and the south. But careful comparison generally shows that either the northern or the southern invasion is by far the more sweeping in a particular epoch. For instance, in the Oxfordian and Albian times the inundations in northern Eurasia and North America attained, without much doubt, a greater extent than did the local invasions in the southern areas. The reverse is the case with the Kimmeridgian and Cenomanian transgressions. The southern phases of these transgressions obviously far exceed, in extent, the northern ones that have been generally referred to the same respective epochs. As to the Volgian deposits, the correlation of the several series in different basins of Russia is, as yet, not altogether free from doubt. Certain palæontological facts seem to suggest that there was a tendency for the Volgian water to shift southward towards the Upper Volgian time. And it will not be surprising if some of the so-called Upper Volgian formations in the Arctic ultimately prove to be of lowest Neocomian age.

Finally, it may be remarked that the extent of a general marine trans gression in low latitudes is, in some measure, proportional to the magnitude of the tectonic movement or movements that are to follow. The Maestrichtian transgression, for instance, is far more sweeping than the Urgonian; so is the Laramide a far more important movement than the Austrian. The same rule may be applied to the several cycles of the Jurassic and Tertiary, and perhaps can even be extended to the Palæozoic. This, however, is not to be dogmatically maintained so long as we are unable to apply some quantitative test.

Pending the accumulation of stratigraphical data, it must be freely admitted that the evidences brought forward in this paper are by no means sufficient to determine with finality the relationship between hydrocratic and geocratic movements in the several minor cycles, particularly in such puzzling times as the Volgian and the Albian. As to the grander movements, our principle seems to be however more or less well established. Thus the post-Jurassic movement was preceded by the Kimmeridgian and Tithonian or Portlandian transgression in the south, and followed by the early Neocomian invasion in the north; the post-Cretaceous or Laramide movement was preceded by the upper Cretaceous transgression in the south, and followed by the Thanetian flood in the north; and the mid and late Tertiary movements were preceded by the Lutetian transgression in the south, and followed by the early Quaternary flood in the Arctic.

BIBLIOGRAPHY

1. Anthula, D. J. Ueber die Kreidefossilien des Kaukasus, etc., Beit. Z. Pal. Oesterr.-Ung. u. d. Orients, XII, pp. 53-159, 1899.

2. Böhm, Joh. Ueber die obertriadische Fauna der Bäreninsel. kungl. Svenska Vetensk,-Akad. Handl., XXXIII, pp. 1-76, 1903.

3. Bonarelli, G. Osservazioni sul Toarciano e l'Aleniano dell'Appenino centrale. Boll. Soc. Geol. Ital., XII, pp. 195-254, 1893.

4. Borissjak, A. Die Fauna des Donetz-Jura. I. Cephalopoda. Mém, Com. Géol. N. S. No. 37, 1908.

5. Böse, E. Ueber Lias in Mexico. Zeit. d. d. geol. Ges., L, pp. 168-175, 1908.

6. Burckhardt, C. La faune jurassique de Mazapil, etc. Bol. del. Inst. geol. di Mexico. No. 23, 1906.

7. Blanckenhorn, Max. Beit. zur Geol. Syriens: Die Entwicklung des kreidesystems etc. Eine Geognotisch-paläontologische Monographie, Cassel, 1890.

8. Blanckenhorn, M. Neues zur Geologie und paläontologie Egyptens. II, Das Palaeogen. Zeits. d. d. geol. Ges., LII, pp. 403-479, 1900.

9. Baumberger, E. Ueber Facies und Transgressionen derunteren Kreide am Nordrande der Mediterrano-helvetischen Bucht im westlichen Jura. Wiss. Beilage zum Berg. d. Töchterschule in Basel. 1901.

10. Boussac, J Distribution des niveaux et des facies dans le Nummulitique dit autochtone de la Suisse orientale, C. R. Ac. Sc. CL, pp. 1272-1274, 1910: Nummulitique helvétique et Nummulitique préalpin dans la Suisse centrale et orientale, Ibid., CL, pp. 1555-1557, 1910; Observations sur le Nummulitique des Alpes Suisses. Bull. Soc. géol. France. 4e sér., IX, pp. 178-196, 1910.

11. Boussac, J. Revision du Nummulitique alpin. Bull. Serv. Carte géol. France XX, pp. 548-553, 1910.

12. Bogdanowitch, C. Notes sur la Géologie de l'Asie centrale, I, Description de quelques depôts sédimentaires de la contrée transcaspienne et d'une partie de la Perse septentrionale. Verh. d. k. russ. Miner. Ges., 2e sér., XXVI, pp. 1-192, 1890.

13. Benoist, E. l'Etage oligocène moyen dans la commune de Gass (Landes). Bull. Scient. de la Soc. de Borda à Dax. pp. 54-61, 1883.

14. Canavari, M. La fauna degli strati con Aspidoceras acanthicum di Monte Serra presso Camerino. Palaeontogr. Ital., II-IV, VI, LX, 1896-1903.

15. Choffat, P. Contribution à la connaissance des colonies portugaises d'Afrique. I, Le Crétacique de conduica; II, Nouvelles donnés sur la zone littorale d'Angola, Commis. du Serv. Géol. Portugal. 1903, 1905

16. ——— Recueil de monographies stratigraphiques sur le système crétacique du Portugal. Direct. des Serv. géol. du Portugal. 1885-1900.

17. Coquand, H. Note sur la Craie supérieure de la Crimée etc. Bull. Soc. géol. France, 3e sér., V, pp. 86-99, 1877.

18. Carez, L. La Géologie des Pyrénées françaises. Mém. Carte Géol. dét. France. 6 Fasc., 1904-1909.

19. Cechia-Rispoli, G. La Seria nummulitica dei dintorni di Termini-Imerese. Giorn. di Sc. Nat. ed Econom. di Palermo. XXVII. pp. 53-137, 1909.

20. Clark, W. B. and Martin, G. C. The Eocene Deposits of Maryland. Maryland Geol. Surv, Eocene, 1901.

21. ——— Correlation Papers, Eocene, Bull. U. S. Geol. Surv., No. 83, 1891.

21a. Chudeau, R. Recherches sur la tectonique de l'Afrique occidentale; Bull. Soc. géol. France, Sér. 4, Vol. 18, pp. 59-87, 1918.

22. Diener, C. Fauna of the Tropite Limestone of Byans. Palaeontologia Indica. Ser. XV, V, I, 1906.

23. Dereims, A. Recherches géologiques dans le Sud de l'Aragon, Annales Hébert, II. 1898.

24. Dacqué, E. Beiträge zur Geologie des Somalilandes. II, Ober Jura. Beit. z. Palaeont. Oesterr.—Ung., XVII, pp. 119-159, 1905.

25. Dawson, G. M. On the earlier Cretaceous rocks of the north-western portion of the Dominion of Canada. Amer. Journ. Sc. 3rd Ser., XXXVIII, pp. 120-127, 1889.

26. Duncan, P. M. A description of the Echinodermata from the strata on the south-eastern Coast of Arabia. Q. J. G. S. XXI, pp. 349-363, 1865.

27 Douvillé, H. Examen des fossiles rapportés du choa par M. Aubry. Bull. Soc. géol. France. 4e sér VIII, pp. 144-151, 1908.

28. ——— Mission scientifique en Perse par J. de Morgan. IV. paléontologie. pp. 191-380, 1904.

29. ——— Le Terrain nummulitique du bassin de l'Adour Bull. Soc. géol. France, 4e sér, V, pp. 9-55, 1905.

30 ——— Sur quelques gisements à Nummulites de l'Est de l'Europe. Bull. Soc. géol. France. 4e sér., VIII, pp. 266-267, 1908.

31. ——— Paléontologie de Madagascar. II, Sur quelques Gisements nummulitiques de Madagascar. Annales de Paléont. I. pp. 61-68, 1906.

32. ——— Les Foraminiféres dans le Tertiaire de Bornéo. Bull. Soc. géol. France. 4e sér., V. pp. 435-464, 1905.

33. Dall, W. H. A Table of the North American Tertiary Horizons, Correlated with one another and with those of western Europe, with Annotations. 18th Ann. Rep. U. S. Geol. Surv., II, pp. 323-348, 1898.

34. Douxami, H. et Révil, J. Note sur les terrains tertiaires du plateau des Déserts, pres Chambéry. Bull. Serv. Carte. Géol., X. pp. 309-329, 1898.

35. Frech, F. Arthaber, G. V. Lethaea Geognotica. II, Das Mesozoicum I, Trias.

36. ———— Ueber das Paläozoicum in Hocharmenien und Persien. Beit. z. pal. Oesterr.-Ung., XII, pp. 161-308, 1900.

37. Frech, F. Geologie kleineasiens.

38. Futterer, K. Beiträge zur Kenntniss des Jura in Ost-Afrika, Zeits. d.d. geol. Ges. XLVI, 1-49, 1893; XLIX, pp. 568-627, 1897.

39. Fourteau, R. Contribution á l'étude de la faune crétacique d'Egypte, Bull. de l'Inst. Egyptien. 4e ser., IV, pp. 231-349, 1904.

40. Fedorow, E. Die Kreide- und Geschiebelehmablagerungen am Ostfusse des nördlichen Ural. Isw. Geol. Kom., 1887

41. Fugger, E. Das Salzburger Vorland. Jahrb. d. k. k. geol. Reichsanst., XLIX, pp. 287-428, 1899.

42. Gentil, L. Recherches stratigraphiques sur le Maroc oriental. C. R. Ac. Sc., CXLVI, pp. 427-430, 1908.

43. Gautier, E. F. et Chudeau, R. Missions au Sahara, I, Sahara, algérien. paris, 1908.

44. Greco, B. Il Lias superiore nel circondario di Rossano Calabro. Bull. Soc. geol. ital., XV, pp. 92-121., 1896.

45. Grabau, A.W. Stratigraphy of China. Part II, 1928.

46. ———— Summary of Cenozoic and Psychozoic Desposits. Bull. Geol. Soc. China. vol. VI, No. 2. pp. 157-158, 1927.

47. ———— Summary of Cenozoic and Psychozoic Deposits Bull. Geol. Soc. China. vol. VI, No. 2. p. 160. 1927.

48 Grossouvre, A. Recherches sur la Crais supérieure. Mém Carte Géol. dét. France; I, Stratigraphie generale. 1901.

48a. Gregory, J.W. The Rift Valleys and Geology of East Africa, 1921.

49. Geologische Untersuchungen und Schürfungen längs der Sibirischen Eisenbahn. Ausgabe des Bergdepartment. Lieferung 22, St. Pet.

50. *Ibid* L. 5, 1896.

51. Haug, E. Les Géosynclinaux et les aires continentales, contribution à l'étude des transgressions et des régressions marines. Bull. Soc. géol. France. 3e sér., XXVIII, pp. 617-711, 1900.

52. ———— Traité de Géologie. a, p. 897; b, p. 1015; c, p. 1021; d, pp. 1068-1069; e, pp. 1250-1251; f, p. 1194; g. pp. 1268-1275 et 1278-1279; h, p. 1332; i, pp. 1486-1487; j, p. 1507.

53. Hayden, H. H. The Geology of the Provinces of Tsang and U in Central Tibet, Mem. Geol. Surv. India. XXXVI, pp. 1-80, 1896.

54. Hyatt, A. Trias and Jura in the Western States. Bull. Geol. Soc. America. VI, pp 395-434, 1894.

55. Ilovaisky, D. l'Oxfordien et le Séquanien des gouvernements de Moscou et de Riazan. Bull. Soc. Natur. Moscou, N. S. XVII, pp. 222-292, 1903.

56. ——— Das Ljapinland. Skizze der Geographie und Geologie. Arb. d. Geol. Abt. d. Mosk. Ges. d. Liebh. d. Nat., Ant. u. Ethno., L. I 1915.

57. Joleaud, L. Sur les faunes d l'Eocone inferieur et moyen du sud algérien et tunisien. Bull. Soc. géol. France, 4e sér., VIII, pp. 295-297, 1908.

58. Jacquot et Munier-Chalmas. Sur l'existence de l'Eocène inférieur dans la Chalosse etc., C. R. Ac. Sc., CII, pp. 1261-1264, 1886.

59. Jahresberichte des Russ. Geol. Komit. für die Jahre 1912-1919; Isw., Geol. Komit. 1913-20.

60. Kilian, W. et Révil, J. Contributions à la connaissance de la zone du Briançonnais. Série suprajurassique. Ann. d. l'Univers. Grenoble, XV, pp. 533-559. 1903.

61. Koch, L. Stratigraphy of East Greenland, American Journal of Science, vol. XII, 5th Ser., No. 88, pp. 346-349, 1928.

62. Kossmatt, F. Untersuchungen über die südindische Kreideformation Beit. z. pal. Oesterr.-Ung., IX, pp. 97-203; XI, pp. 1-46; 1895-1898

63. ——— The Cretaceous Deposits of Pondicherri. Rec. Geol. Surv. India. XXX, pp. 52-100, 1897.

64. Karakasch, N. I. Le Crétacé inferieur de la Crimée et sa faune. Tr. Soc. Natur. St. Pét. XXXII, Sect. géol. et Min. 1907.

65. Kryshtofovitch, A. Jahresberichte der Sibirischen Abteilung des geol. Komit. für die Jahre 1919 bis 1923. Isw. Sib. Geol. Tomsk, 1918; Uber die Kreideflora von russisch-Sachalin. Isw. Geol. Kom. St. Pet. 39, 1920.

66. Kassino, N. Hydrogeologische Untersuchung in S. W. Teil des Bezirks Irgis. St. Pet. 1914.

67. Lundgren, B. Anmärkningar om Faunan i Andöns Jurabildningar. Christiania Vedensk. Selsk. Forth., No. 5. 1894.

68. Logan, W. N. A North American Epicontinental Sea of Jurassic Age: Journ. Geol., VIII, pp. 241-273. 1900.

69. Lee, J. S. The Fundamental Cause of Evolution of the Earth's Surface-features. Bull. Geol. Soc. China. vol. V, No. 3-4, 1926.

70. Lahusen, J. Die Inoceramenschichten am Olenek und der Lena. Mém. Ac. Sc. VII S., 33. Nr. 7. 1886.

71. ——— Ueber russische Aucellen. Tr. Geol. Komt. VIII, Nr. 1, 1888.

72. Leymrie, A. Description géol. et paléont. des pyrénées de la Haute-Garonne. Toulouse. 1881.

73 Lemoine, P. Afrique occidentale, Hundb. d. Regionalen Geologie. vol. VII, 6A, part 14, 1913.

74. Mojsisovics, E. V. Die Hallstätter Entwicklung der Trias. Sitzungsber. d. k. Akad. d. Wiss. in Wien, Math.-Naturw. kl. CI, I, pp. 769-780, 1892; Ueber den Chronologischen Umfang des Dachstein-Kalkes; Ibid. CV, I, pp. 7-40, 1896.

75. ———— Arktische Triasfaunen. Mém. de l'Acad. Impér. de Sc. St-Pét., 7e Sér. XXIII, No. 6, pp. 1-159, 1886.

76. Meneghini, J. Monographie des Fossiles du Calcaire rouge ammonitique de Lombardie et de l'Appennin central. Paléont. Lombarde, 4e Sér. 1867-1881.

77. Madsen, V. On Jurassic Fossils from East Greenland. Meddelelser om Grönland. XXIX, pp. 157-210, 1904.

78. Middlemiss, C. S. The Geology of Hazara and the Black Mountain. Mem. Geol. Surv. India. XXVI, 1896.

79. Neumayr, M. Uber den Lias in südöstlichen Tirol. u. in Venetian. N. J. F. M., 1881, I, pp. 208-226.

80. ———— Jurastudien. Jahrb. d. k. k. Geol. Reichsanst. XX, pp. 549-558, 1870; XXI, pp. 297-378, 450-536, 1871.

81. Neumayr, M. et Uhlig, V. Ueber die von H. Abich in Kaukasus gesammelten Jurafossilien. Denkschr. d. math.-naturw. kl. d. k. Akad. d. Wiss., LIX, pp. 1-122, 1892.

82. Newton, E. T. Notes on a collection of rocks and fossils from Franz Josef Land, made by the Jackson-Harmsworth Expedition during 1893-1896. Q. J. G. S. LIII, pp. 477-518, 1897

83. Nopca, Baron Franz. Zur Geologie der Gegend zwischen Gyulafehérvár, Déva, Ruszkabánya und der Rumanischen Landesgrenze. Mitt. a. d. Jabrb. d. k. Ungar. Geol. Anst., XIV. pp. 93-279, 1905.

84. R. B. Newton. On some fossils from the Nubian Sandstone Series of Egypt. Geol. Mag. pp. 388-397 1909.

85. ———— The Tertiary Fossils of Somaliland. Q. J. G. S. LXI, pp. 155-180, 1905.

86. Noetling, F. Fauna of Baluchistan. 1. 3. Fauna of the Upper Cretaceous (Maestrichtian) Beds of the Mari Hills. Palaeont. Indica, Ser. XVI, 1897.

87. Obrutschew, W.A. Geologie von Sibirien, Fortschritte der Geologie und Palaeontologie, Heft 15, Berlin, 1926.
a, pp. 268-269; b, pp. 293-294; c, pp. 337-338; d, p. 343; e, pp. 356-378; f, pp. 301-386.

88. Oppenheim, P. Ueber einige alttertiäre Faunen der Osterr.-Ung Monarchie. Beit. z. pal. u. Geol. Osterr.-Ung., XIII, pp. 141-277, 1901.

89. ———— Zur Kenntniss alttertiärer Faunen in Egypten Palaeonotographica, XXX, 1903-1906.

90. ——— Beit. z. Kenntniss des Oligacän und seiner Fauna in der venetianischenVoralpen. Zeits. d.d. Geol. Ges., LII, 1900; Das Alttartiär der Colli Berici in Venetian, die Stellung der schichten von Priabona und Oligocäne Transgression im alpinen Europa. *Ibid.*, XLVIII, pp. 27-152 1896.

91. Pavlow. A. Die Cephalopoda des Jura und der Unterkreide des nordlichen Sibirien. Mém, Ac. Sc., VIII S., XXI, Nr. 4, 1914.

92. Pavlow, A.P. et Lamplugh, G.W. Argiles de Speeton et leurs équivalants. Bull. Soc. Natur. Moscou. N.S. V, pp. 455-570, 1892.

93. Pavlow, A.P. Enchainement des Aucelles et Aucellines du Crétacé russe. Nouv. Mém. Soc. natur. Moscou. XVII, 1907.

94. Pinz, G.D. Le Alpi Feltrine. 1907.

95. Pompeckj, J.F. The Jurassic Fauna of Cape Flora, Franz Josef Land. The Norwegian North Polar Exped. 1893-1896, Scientific results. I, No. 2; A.G. Nathorst. Fossil Plants from Franz Josef Land. *Ibid.* No. 3. 1900.

96. ——— Marines Mesozoicum von König-Karls-Land. Öfvers. af K. Vetensk.-Akad. Förhandl., 1899, No. 5. pp. 449-464.

97. ——— Jura-Fossilien aus Alaska. Verh. d.k. Russ. Min. Ges., 2 Ser., XXXVIII, pp. 239-278, 1900.

98 Polevoi, J. Das Anadyrland. Die Wichtigsten Resultate der Anadyrexpedition. Tr. Geol. Komt. NS. 140, 1915.

99. Pellat, E. et Cossmann, M. Le Barrémien supérieur à faciès urgonien de Bronzet-lez-Alais (Gard). Mém Soc. géol. France, No. 37, 1907.

100. Popovici-Hatzeg, V. Contribution a l'étude de la faune du Crétacé supérieur de Roumanie. Mém Soc. géol. Fr. Paléont., No. 20, 1900.

101. Prigorowski M. Uber einige Sedimentfolgen westlich und östlich vom Mugodscharge-birge. Isw. Geol. Kom. 1912. Nr. 8.

102. ——— Zur geologie des westlichen Teils der Kirgisensteppe. Geol. Wiest. IV, 1918-1921.

103. Pareto, L. Note sur les subdivisions que l'on pourrait établir dans les terrains de l'Apennin septentrional. Bull. Soc géol. France., 2e Sér, XXII, pp. 210-277, 1865.

104. Roman, F. Note sur le Jurassic inférieur et meyen des environs de Saint-Ambroix (Gard). Annales Soc. Linn. de Lyon, LVI, 1909.

105. Raciborski, M. Flora kopalna ogniotrwalych glinek krakowskich. I, Rodniowce. Pamietnik Akad. Umiejetnosci w Krakowie, XVIII. pp. 143-243, 1894.

106. Rothpletz, A. Die Perm.-, Trias-, und Juraformation auf Timor u und Rotti im indischen Archipel. Palaeotogr., XXXIX, 1892.

107. Retowski, O. Die Tithonischen Ablagerungen von Theodosia. Bull. Soc. Naturw. Moscau. N.S. VII, pp. 206-301, 1894.

108. Ravn, J.P. The Tertiary Fauna at Cape Dalton in East-Greenland. Meddelelser om Grönland, XXIX, pp. 93-140, 1904.

109. Sokolow, D.N. Mesozoische Versteinerungen von den Inseln Preobradschenie und Begitschew. Tr. Geol. Mus. IV, 1910 L. 3; VIII, 1914. L. 9.

110. ———— Ueber Akad. F. Schmidts Fossiliensammlung aus dem Amurland. Tr. Geol. Mus. VI, 1912, L. 6.

111. ———— Die kreide-Inoceramen des russischen Sachalin. Tr. Geol. Kom., NS., 83, 1914

112. Stanton, T. W. A Comparative Study of the Lower Cretaceous formations and faunas of the United States. Journ. of Geol. V. pp. 579-624, 1897.

113. Schuchert, C. Paleogeography of North America. Bull. Geol. Soc. America. vol. 20. 1910. a, p. 505 et seq.; b, p. 583; c, pp. 584-585; d, 587-597.

114. ———— Sites and Nature of the North American Geosynclines. Bull. Geol. Soc. America. vol. 34; 1923: a, p. 191; b, p. 194; c, p. 229. map. 17.

114a. ———— The Theory of Continental Drift, pp 116-117, 1928

115. Stille, H. Grundfragen der Vergleichenden Tektonik.

116 Sayn, G. et Roman, F. L'Hauterivien et le Barrémien de la rive droite du Rhône et du Bas-Languedoc. Bull. Soc. géol. France. 4e Sér, IV, pp. 607-640, 1904.

117. Di-Stefano, G. Sulla presenza dell' Urgoniano in Puglia. Bull. Soc. geol. ital., XI, pp. 677-682, 1893.

118. Semenow, W.P. Faune des dépôts crétacés de Manghychlak etc. Trav. Soc. Natur. de St-Pét., Géol. et Minér. XXVIII, pp. 1-178. 1899.

119. Schmidt, F. Mitt. über paläont. Sammlungen von Sljunin von der Küste des Ochotsdmeeres. Sap. Min. Ges. XXXVIII, L. 2, 1900.

120. Schubert, R. Zur Stratigraphie des istrisch-norddalmatinischen Mitteleocäns. Jahrb. d.k.k. Geol. Reichsanstalt. LV, pp. 153-188, 1905.

121. ———— Kreide und Focänfossilien von Ordu am Schwarzen Meere (Kleinasien). Verh. k.k. geol. Reichsast., 1907.

122. Scholz, E. Beit. z. Kenntniss der deutsch-ostafrikanischen Tertiärablagerungen. Monatsber. d.d. geol. Ges., 1910.

123. Toll, E. Skizze der Geologie der Neusibirien Inseln und die Wichtigsten Aufgaben der Erforschung der polarländer. Mém. Ac. Sc., VIII, S., 9, Nr. 1. 1899.

124. Thomas, P. Essai d'une description géol. de la Tunisie. II Stratigr. d. Terrains paléoz. et Mésoz. Exp. Scient. Tunisie. Paris, 1907, 1909.

125. Teisseyre, W. Der paläozoiche Horst von Podolien und die ihn umgebenden Senkungsfelder. Beit. z. pal. u. Geol. Oesterr.-Ung., XV, pp. 101-126, 1903.

126. Toula, F. Geologische Untersuchungen in centralen (und östlichen) Balkan. Denks. d. math.-naturw. Cl d. k. Akad. d. Wiss., LV, 2, pp. 1-108, 1889; *Ibid.*, LVII, 2. pp. 323-400, 1892.

127. Teller, F. Oligocänbildungen im Feistritzthal bei Stein in Krain. Verh. d. k. k. geol. Reichsanst., 1885, pp. 193 200.

128. Uhlig, V. Bau und Bild der Karpaten. 1903; Ueber die Tektonik der Karpaten, Sitzungsber. d.k.k. Akad. d. Wiss. in Wien, Math.-Naturw. kl., CXVI, pp. 871-982, 1907.

129. ———— Ueber die Fauna des rothen Kellowaykalkes der penninischen klippe Babierzówka bei Neumarkt. in West-Galizien. Jahrb. d.k.k. geol. Reichsanst. XXXI, pp. 381-422, 1881.

130. ———— Zur Kenntniss der Cephalopoden der Rossfeldschichten. Jahrb. d.k.k. geol. Reichsanst., XXXII, 1882; Ueber Neocome Fossilien vom Gardenazza in Südtirol etc. Ibid. XXXVII, 1887

131. Vredenburg, E.W. The Cretaceous Orbitoides of India. Rec. Geol. Surv. India. XXXVI, pp. 171-213, 1908.

132. ————. The Stratigraphy of the Ranikot series, Pal. Indica. N.S. vol. III, pt. I. 1909.

133. Verbeek, R.D.M. et Fennema, R. Description géologique de Java et Madoura. Amsterdam, 1896.

134. Wadia, D.N. Geology of India. pp. 206-209, 211-224, 1926.

135. Handbuch der Regionalen Geologie, Heften 10, 14, 17-19, 21-23, 25-26.