ten Namen und Verbreitungsgrenzen auf und zeigt, wie die Tiere „im freiern Verhältniß zu Clima und zu absoluter Erhebung nur theilweise an die Vegetationsverbreitung geknüpft, weniger an den Boden gebunden, nach Lebensart, Nahrung und andern Umständen auf weitere oder engere Kreise angewiesen, ganz andern Gesetzen folgen, ganz andere Verbreitungssphären einnehmen, die aber bisher noch weniger als die vegetativen übersichtlich waren" [48].

Bei seinen Vorarbeiten mußte er noch auf die „Tabula mundi" zurückgreifen, die E. A. W. ZIMMERMANN um 1760 entworfen hatte [49]). Dieser hatte die Verbreitungsgrenzen für Elch und Ren sowie die Nordgrenze des Elefanten und baktrischen Kamels in Asien festgelegt; auch hatte er das Wachsen der Artenmannigfaltigkeit von den Polen zum Äquator abgeschätzt. GOTTFRIED REINHOLD TREVIRANUS hatte die Grundzüge der klimatischen Verschiedenheiten in der Tierwelt entwickelt [50]).

RITTER bereicherte seine Karte durch die Verbreitungsgrenzen von Lemming, fliegendem Eichhorn, Kamel, Stachelschwein, Mufflon, Argali und Büffel. Unter den Handzeichnungen, die er dreißig Jahre später der Akademie vorlegte, befand sich eine Karte über die geographische Verbreitung des Kamels, die in einer Überarbeitung durch JACOB MELCHIOR ZIEGLER überliefert ist [51]).

Als BERGHAUS bei der Vorbereitung der tiergeographischen Abteilung seines „Physikalischen Atlas" nach Unterlagen suchte, fand er nur HERMANN SCHLEGELS „Essai sur la Physionomie des Serpens" (Amsterdam 1837) als ein geeignetes Kartenwerk vor. Er mußte daher für die tiergeographische Abteilung des „Physikalischen Atlas" die Vorarbeiten selbst leisten.

Wie für die Physische Geographie galt es auch für die „Ökonomische Geographie", unter der RITTER die Beschreibung der Kulturverhältnisse verstand (Bem. S. 204), Karten zu entwerfen. Die einzige Karte dieser Art, die in den „Sechs Karten von Europa" erschien, ist die „Tafel über die Bewohner von Europa, über Volksmenge und Bevölkerung dieses Erdtheils" (Tafel VI). In ihr sind die Namen der im Text beigegebenen Völkertafel eingetragen. Die Volksdichtewerte sind in Ziffern beigeschrieben.

Vor RITTERS Arbeit hatte BUFFON 1749 die geographische Verbreitung der Völker skizziert, JOHANN FRIEDRICH BLUMENBACH 1776 und 1790 das Menschengeschlecht auf anthropologischer Grundlage gegliedert und DON LORENZO HERVÁS Y PANDURO 1800 durch Gruppierung der Sprachen nach ihrer grammatischen Übereinstimmung den Weg eröffnet, die Völker genealogisch zu vereinigen.

Bevor BERGHAUS die ethnographischen Übersichts- und Spezialkarten von Europa für den „Physikalischen Atlas" entwarf, war durch FRANZ BOPPS Vergleichende Sprachwissenschaft die wissenschaftliche Grundlage der Ethnographie gelegt worden. So ist auf ethnographischem Gebiet der Gegensatz zwischen den Karten RITTERS und BERGHAUS' besonders groß.

RITTER war davon überzeugt, daß der durch die „Sechs Karten von Europa" eingeschlagene Weg des geographischen Betrachtens „die große Weltansicht, das Detail nicht als Detail, sondern in bezug auf das Ganze zu denken," vorbereite. Erwartungsfroh warf er die Frage auf: „Muß nicht durch diesen Gang das Studium der Geographie sehr vereinfacht und wissenschaftlicher (d. h. nach inneren Gesetzen) geordnet werden?" (Bem. S. 211). So ließ er die „Sechs Karten von Europa" aus der Erziehungsanstalt Schnepfenthal, in der er einst selbst erzogen worden war, als ein „kostspieliges und zeitraubendes Werk" vor die Öffentlichkeit treten: „Ich biete dem Publikum meine geringe Arbeit an, weil ich nach meiner Meynung von ihrem Nutzen beym Unterricht der Jugend überzeugt bin und kein anderes Werk kenne, in welchem dieselben Gegenstände ähnlich behandelt wären" (Vorrede zum Atlas).

[48]) RITTER, CARL in: Abhandlungen der Akademie der Wissenschaften zu Berlin aus dem Jahre 1836. Philosophisch-historische Abhandlungen S. 216.

[49]) ZIMMERMANN, EBERHARD AUGUST WILHELM: Tabula Mundi Geographico Zoologica sistens Quadrupedes hucusque notos sedibusque suis adscriptos (ohne Maßstab, etwa 1 : 50 000 000). Augsburg (ca. 1760).

[50]) TREVIRANUS, GOTTFRIED REINHOLD: Biologie oder Philosophie der lebenden Natur. Göttingen 1802–1822 (6 Bde.).

[51]) Karte über die geographische Verbreitung des Kamels nach einer Handzeichnung von Carl Ritter reducirt und vermehrt mit der geographischen Verbreitung der Dattelpalme *(Phoenix Dactilifera)* durch Jacob Melchior Ziegler. Zu Ritters Erdkunde Bd. XIII, pag. 609–858 (Maßstab 1 : 20 000 000). Berlin o. J. – Einen Ausschnitt aus Zieglers Karte veröffentlichte E. LEHMANN in: Die Erde 90. 1959, S. 220.

QUATERNARY TEMPERATURE CHANGES IN CENTRAL EUROPE

With 1 figure

TOMISLAV ŠEGOTA

1. Introduction

Zusammenfassung: Quartäre Temperaturänderungen in Mitteleuropa

Quartäre Temperaturänderungen wurden durch mehrere Faktoren unterschiedlicher Rangordnung verursacht, die gleichzeitig zusammenwirkten:

1) Die Wärme-Isolierung des arktischen Beckens sowie des antarktischen Kontinents wurde durch eine äußerst langsame Wanderung der Pole gegen die Antarktis bzw. gegen die rund um das arktische Becken gelegenen Kontinente hervorgerufen. Die allgemeine Abkühlung des Klimas infolge der thermischen Isolation der höheren Breiten bildete den Hauptfaktor, den alle weiteren Faktoren geringerer Bedeutung nur noch überlagern konnten.

Diese Erscheinung ist z. T. mit verantwortlich für die fundamentale Tatsache, daß jedes folgende pleistozäne Glazial bzw. Interglazial etwas kühler war als das vorausgegangene. Kurz, das quartäre Eiszeitalter war durch ein allgemeines Kühlerwerden des Klimas ausgezeichnet.

2) Die Bedingungen, die zu einer Vereisung führen, waren auf dem antarktischen Kontinent günstiger als auf der Nordhemisphäre; der Vereisungsbeginn kann auf dem antarktischen Kontinent bis vor den Beginn des Pleistozäns zurückverfolgt werden. Die erste Eiszeit auf der Nordhalbkugel – und gleichzeitig auf der ganzen Erde überhaupt – war die Mindel-Eiszeit. Das wiederholte Vorstoßen und Zurückweichen der riesigen nordhemisphärischen Inlandeis-

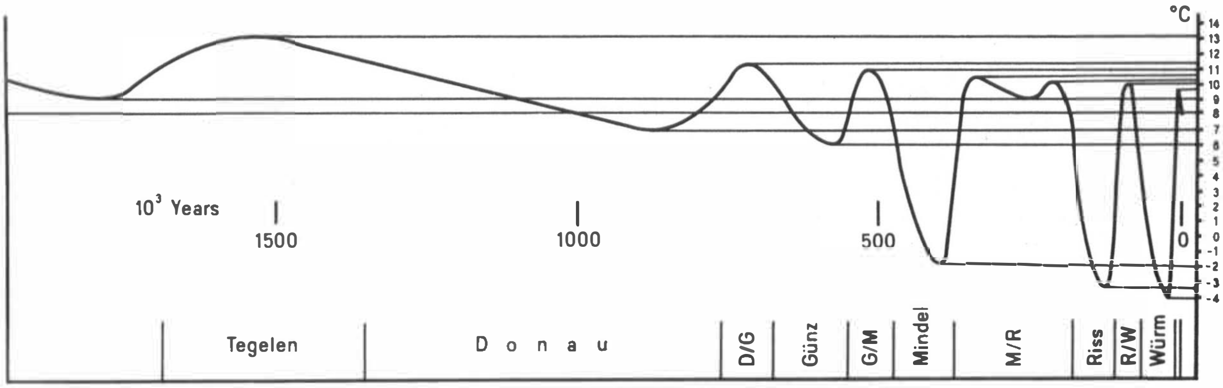

Fig. 1: The curve of the Quaternary temperature changes in Central Europe

massen im Mindel und den darauffolgenden Eiszeiten, mit dem ein entsprechender Vorstoß und Rückzug der antarktischen Eismasse einherging, war der zweite Faktor, der die quartären Temperaturen beeinflußte.

3) Den dritten Faktor bildete das Pulsieren des grönländischen Inlandeises zusammen mit der wechselnden Ausdehnung des Eises im Nordpolarmeer. Der Temperatureinfluß des Grönland-Eises war offensichtlich und klimatisch bedeutsam vor allem in den Zeiten, in denen auf der Nordhalbkugel keine weiteren Eismassen vorhanden waren.

Die eiszeitliche Temperaturkurve (Fig. 1) zeigt nur unvollständig und sehr allgemein den Einfluß der verschiedenen genannten Faktoren. Schwankungen in der Mächtigkeit der antarktischen Eiskappe bereits vor der Mindel-Eiszeit haben zusammen mit dem Einfluß des grönländischen Inlandeises und dem Eis im arktischen Ozean die Temperaturschwankungen im oberen Pliozän, im Pleistozän vor der Mindel-Eiszeit und während des Mindel-/Riß-Interglazials bewirkt. Das kurzfristige Pulsieren des grönländischen Inlandeises sowie die wechselnde Erstreckung des Eises im arktischen Ozean bildeten die beiden Hauptfaktoren für den allmählichen Temperaturabfall nach einem Klimaoptimum sowie auch für manche andere nur geringfügige Temperaturänderung in vergangenen Interglazialen.

4) Das Würm-Glazial war die kälteste Periode der quartären Vereisung.

5) Das quartäre Eiszeitalter ist noch weit von seinem endgültigen Abschluß entfernt.

The form and intensity of organic life, like all physical and geochemical processes on the earth, are very closely related to the temperature. The end of the Tertiary and all of the Quaternary were characterised by profound climatic changes, or the alternation of warm and cold periods, as a result of fundamental temperature changes. In certain periods the temperature was enough low (and the precipitation ample) to enable the origination and development of enormous ice sheets. Detailed investigations have revealed (at least in the northern hemisphere) that cold periods have been separated by warm periods when the temperature was similar as at present, but in certain periods it was even higher than to-day.

The trouble is that on deeper penetration into the past the details rapidly disappear; we can trace only the paleotemperature changes of the higher order of magnitude and in many cases we must be satisfied with the fact that the temperature was "slightly higher", "higher", or "slightly lower" or "lower" than to-day, or "similar to the recent temperature".

"Interpretation of climatic changes . . . beyond the range of written records is a fascinating field for speculation" [1]). So the reconstruction of past temperature changes sometimes is much more the result of the author's inclination to a certain theory than the effect of a study of the facts. (The best example is the well-known studies of temperature changes of the superficial waters in the equatorial Atlantic and Caribbean undertaken by C. Emiliani [2]) who states that: "Most cores indicate that the following temperature minimum, stage 2, was the coldest episode of the Pleistocene. It is possible that the earth was never so cold, at least since the Permo-Carboniferous glaciation or possibly since the beginning of geologic time". In spite of such an important conclusion, the author – under the influence of astronomic hypotheses – in his well known diagram [3]) presented that temperature maxima and minima have reached the same values repeatedly, implying that the temperatures of the major glacial maxima were alike, as were also the temperatures of the interglacials.)

In this article the present author attempts to bring into accordance with the facts so far known his concepts about the general course of the Quaternary glaciation [4]). He conceives of the Quaternary glaciation as a more or less r e g u l a r mechanism. Unhomogeneity of natural environment, possibly disrupted development of glaciation in certain phases, and asynchronous origin of the ice sheets in the northern and southern hemispheres, enormously complicated the temperature changes during the Quaternary period. The paleotemperature changes in the Upper Pliocene and in the Pleistocene epochs are plotted against the

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[1]) Terasmae, J.: Notes on Late-Quaternary Climatic Changes, Annals of the New York Academy of Sciences, Vol. 95, New York 1961, 633.

[2]) Emiliani, C.: Paleotemperature Analysis of Core 280 and Pleistocene Correlations, J. Geology 66, 1958, 270.

[3]) Emiliani, C.: Pleistocene Temperatures, J. Geology 63, 1955, 569, fig. 15.

[4]) Šegota, T.: Geografske osnove glacijacija, Radovi Geografskog instituta 4, Zagreb 1963. (The Geographical Background to Ice Ages, in Croatian language with English summary.)

hypothetical chronology inferred by the present author [5]).

By far the greatest part of paleoclimatic data have been derived from the northern hemisphere. Our paleotemperature curve (Fig. 1) is based on data from Central Europe. Climatic differences between various part of the world existed then as they do to-day; the general course of the temperature was the same but the amplitude was different.

II. The factors which influenced the temperature changes during the Quaternary glaciation

Like all other natural processes, the Quaternary glaciation did not originate unexpectedly and suddenly. Long, long before the origin of the ice sheets, climatic conditions were created (one of them was the lowering of temperature) which were indispensable for their development. There was a long period of preparation for the glaciation. (W. Meinardus wrote about the "Eiszeitbereitschaft" of the earth.)

The origin of the glaciation can be defined as the creation of the geographical environment for the optimal relation between the quantity of precipitation and the temperature, or the accumulation and the ablation. The optimal glaciogenic combination of precipitation and temperature can be achieved by the interrelation between three factors: (a) the vicinity of the pole, (b) a favourable geographical distribution of land and sea, and (c) orogenic and epeirogenic movements. The vicinity of the pole determines the annual march of the temperature, i.e. the amount of summer ablation. A suitable distribution of land and sea enables the transport of humid maritime air to the continent which will be glaciated. Orogenic and epeirogenic movements create a high relief, and the close relationship between a high relief and the glaciation in its first phase is a well-known fact. So we can conclude that the glaciation originates when the land-mass (or masses) of continental dimensions, in a phase of orogenic and epeirogenic movements, is located in high latitudes.

From the time when the ice sheet (and the frozen sea) becomes a geographic factor, all three initial factors lose any significance for the future evolution of the glaciation. The ice sheet is no longer just a passive consequence, it becomes an active geographic factor which changes the natural environment.

In this manner, one must distinguish two factors which caused the cooling during the Quaternary glaciation. The drop of temperature in the pre-glaciation period was very slow and it was caused by an equally slow migration of the poles to the future glaciated lands. Relatively rapid expansion of the glaciated areas was responsible for the catastrophic drop of temperature in the relatively brief period during the glacial stages. The temperature of the air during the glaciation is a function of the radial extent of the glaciated area; the mere existence of the ice sheet was quite enough to cause further, and now very rapid, cooling of the climate. So we can conclude that the periodic extent of the ice sheets in the northern hemisphere during the glacial stages (Mindel, Riss and Würm) was the cause of the temperature drop which accompanied them. (The cause is well known: the loss of energy due to the high albedo of snow and ice, the loss of heat due to the melting of ice and snow, the increase of cloudiness in subtropical belts, etc.) Accordingly, the drop of temperature during the glacial phases was a consequence (and not the cause) of the radial extent of huge ice sheets in the northern hemisphere and in Antarctica. The periodic waxing and waning of the ice sheets in the northern hemisphere and the pulsation of the Antarctic ice sheet was a second order oscillation which was superimposed on the curve resulting from a general cooling of the earth.

The general evolution of the Quaternary glaciation. Extremely slow cooling of the earth during the Tertiary has been quantitatively proved. During the Mesozoic Era both North and South Pole were relatively far from their present positions. The North Pole was located somewhere in the western Pacific, or in northeastern Asia, and the South Pole was in the southern Atlantic or Indian Ocean. At the beginning of the Tertiary the South Pole was near the Antarctic [6]), and in the Eocene and Oligocene the Pole was in the vicinity of its shore. Antarctic became a subpolar continent: a long polar night slowly but systematicaly lowered the winter temperature [7]).

A similar process began in the northern hemisphere. At the beginning of the Cenozoic Era the North Pole moved into the Arctic Basin [8-9]). The result was a slow cooling of the subpolar sea and land. Accordingly, the same process began simultaneously in both the northern and southern hemispheres, and the cooling of the earth was really an universal process. Shortly, the lowering of temperature during the Cenozoic Era was a direct effect of the approaching of the poles to the huge continental masses of North America, Euro-Asia, and Antarctic.

Bottom-seawater temperatures, determined isotopically from benthonic foraminifera in the equatorial Pacific, show a progressive decrease, from Oligocene through Miocene into late-Pliocene time, of about 8° C [10-12]). This temperature decrease is paralleled in

[5]) Šegota, T.: Absolute Chronology of the Quaternary Period, Bull. Sci., Conseil Acad. R.P.F. Yougoslavie, T. 6, No. 2, Zagreb 1961, 39.

[6]) Irving, E. & Green, R.: Polar Movement Relative to Australia, Geophysical J. 1, 1958, 64.

[7]) Brooks, C.E.P.: Climates through the Ages, London 1950, 133.

[8]) Runcorn, S.: Rock Magnetism, Science 129, 1959, 1002.

[9]) Rukhin, L. B.: Problema proishoždenija materikovyh oledenenij, Izv. Vsesoj. geogr. obšč. 90, 1958, 1, 25.

[10]) Emiliani, C. & Edwards, G.: Tertiary Ocean Bottom Temperatures, Nature 171, 1953, 888.

[11]) Emiliani, C.: Temperatures of Pacific Bottom Waters and Polar Superficial Waters During the Tertiary, Science 119, 1954, 853.

[12]) Dorman, F. H. & Gill, E. D.: Oxygen Isotope Paleotemperature Determinations of Australian Cainozoic Fossils, Science 130, 1959, 1576.

the northern hemisphere [13-16]). The lowering of temperature in 40 million years preceded the formation of Quaternary ice sheets; in this genetic sense the Quaternary glaciation was not at all a sudden phenomenon.

The main geographic characteristic of the Quaternary glaciation is the fact that it was a bipolar glaciation, i.e. enormous ice sheets were developed in both the southern and the northern hemisphere. Besides this, the structure of the glaciation was different; in the Antarctic an unique ice sheet developed, while in the northern hemisphere the ice sheets were not united in one ice body (cellular structure of the glaciation). The possibility of thermal isolation was much more favourable in the southern hemisphere (the land surrounded by the sea) than in the northern hemisphere (the sea surrounded by land). All in all, an ideal combination to enable extreme complexity of the temperature changes.

As the glaciogenic conditions were much more favourable on the Antarctic Continent than in the northern hemisphere, the beginning of the glaciation in the Antarctic can be traced well before the beginning of the Quaternary as commonly defined in the northern hemisphere, some glacial traces derived from the Tertiary [17]). The Antarctic ice sheet had come into existence as the result of the growth of many local glaciers; the mountain glaciation probably started long before the vast ice sheet was formed, probably a few million years before [18-19]). The pulsation of this early Antarctic ice sheet (which the present author conceived of as a regular process) was the cause of relatively slight temperature changes in the Upper Pliocene, which, however, influenced the climate solely in the southern hemisphere. The glaciogenic climate was favourable, and the result was an enormous Antarctic ice sheet. The atmosphere and the oceans are extremely sensitive mechanisms, and it was not possible that such a fundamental change of equilibrium should not influence the climatic parameters and the temperature of the ocean water, but now even in the northern hemisphere. This was a very long period when the glaciation was confined exclusively to the Antarctic. By the mere fact of its existence the Antarctic ice sheet continued the cooling of the earth, and its pulsations (plus the influence of the Greenland ice sheet and the sea ice in the Arctic Basin) were the cause of the oldest slight temperature changes in the northern hemisphere. This is the explanation of the problem why the traces of the older "glacials" (Günz, Donau, and eventually pre-Donau "glacials") in the northern hemisphere are so scanty: there were no ice sheets in the northern hemisphere. Accordingly, by far the greatest part of the Quarternary glaciation was confined to the southern hemisphere. Slight temperature changes, the invasion of the "northern guests" in the Calabrian and Sicilian, first pluvials and first traces of the mountain glaciation (Biber, Donau, Günz), the oldest sea level fluctuations, as well as many other signs of periodic slight cooling and warming in the northern hemisphere, were mainly the effects of the pulsation of the Antarctic and Greenland ice sheets and the extent of sea ice in the Arctic Basin.

A very considerable body of evidence undoubtedly disproves the existence of vast ice sheets in the northern hemisphere during the Günz glacial [20]). It seems that the Günz glacial was only a relatively cool phase; it was of the same order of magnitude as some other pre-Günz "glacials" (better to say cool phases) in the northern hemisphere. The first complete thermal isolation of the Arctic Basin initiated the Mindel glacial. Mindel was in fact the first glacial in the northern hemisphere. The Quaternary glaciation became a bipolar glaciation and this was the beginning – in full sense of the word – of the Quaternary glaciation in the northern hemisphere. The Mindel glacial was the first universal glacial phase, and the paleotemperature curve of the Quaternary period can be divided in two essentially different parts, the pre-Mindel and post-Mindel sections, respectively.

Such general course of the Quaternary glaciation is consistent with recent discoveries. The rate of low latitude atmospheric circulation in the Pacific Ocean in the last 1.5 million years has been represented on an excellent diagram [21]). The intensity of the circulation was much stronger in the phases 2, 4, 6 and even 8 (which correspond to Würm, Riss, Mindel and Günz) than in the older phases. The factor which strongly intensified the atmospheric circulation during the abovementioned phases could only have been the ice sheets in the northern hemisphere. In the phases when there were no ice sheets in the northern hemisphere the atmospheric circulation was much weaker.

A certain number of sediment cores contain a Pliocene-Pleistocene boundary clearly defined by changes in remains of planktonic organismis [22]). Paleotemperatures determined by the oxygen isotopes method show climatic fluctuations similar to those of the Pleistocene but of much smaller amplitude.

It is interesting to note that the ice-rafted detritus in core V 16–66 (southeast from Cape Town) supports

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13) Durham, J.: Cenozoic Marine Climates of the Pacific Coast, Bull. Geol. Soc. America 61, 1950, 1243.

14) Woldstedt, P.: Die Klimakurve des Tertiärs und Quartärs in Mitteleuropa, Eiszeitalter und Gegenwart 4–5, 1954, 5.

15) Szafer, W.: Plioceńska flora okolic Czorsztyna i jej stosunek do Plejstocenu, Inst. Geologiczny, Prace 21, Warszawa 1954.

16) Szafer, W.: Mioceńska flora ze Starych Gliwic na Śląsku, Inst. Geologiczny, Prace 33, Warszawa 1961.

17) Wright, C.S. & Priestley, R.E.: British (Terra Nova) Antarctic Expedition (1910–13), Glaciology, London 1922, 83.

18) Emiliani, C. & Geiss, J.: On Glaciations and Their Causes, Geologische Rundschau 46, 1959, 2, 589.

19) Kotljakov, V.M.: Osobennosti stroenija verhnej tolšči lednikovogo pokrova centralnyh rajonov Antarktidy, Izvestija AN SSSR, serija geografičeskaja 1959, 4, 15: Antarctic I.S. consists of ice more than one million years old.

20) Woldstedt, P.: Norddeutschland und angrenzende Gebiete im Eiszeitalter, Stuttgart 1950.

21) Arrhenius, G.: Sediment Cores from the East Pacific, Reports of the Swedish Deep-Sea Expedition 1947–1948, Vol. V, Fasc. 1, Göteborg 1952.

22) Ericson, D.B., Ewing, M. & Wollin, G.: Pliocene-Pleistocene Boundary in Deep-Sea Sediments, Science 139, 1963, 727.

the faunal evidence for climatic deteriorations during the final phase of the Pliocene[23]). Presumably the drifting ice orignated on the Antarctic Continent. The fact that the detritus first appears in core V 16–66 at about 580 cm below the Pliocene-Pleistocene boundary indicates that the climate of Antarctic had become glacial some 250,000 years before the drastic climatic change that marked the end of the Pliocene epoch. From the rates of accumulation of late-Pleistocene sediments and from the known thickness of Pleistocene sediments above the boundary, one can estimate[24]) the age of boundary to be no less than 800,000 years.

Similarly, bottom temperature of the eastern equatorial Pacific was already similar to the present in Late Pliocene time, suggesting that glaciation of Antarctic was already complete, and ice extended to the sea shores[25]). All this proves that the glaciation of the Antarctic Continent began much before the appearance of the first continental ice sheets in the northern hemisphere.

III. The temperature of glacial and interglacial stages

1. The temperature of Hypsithermal time (Postglacial climatic optimum). Due to regional differences, the estimated temperatures of the post-Würm Climatic Optimum differ considerably. Since the data are derived from the study of organic life, the inferred temperature rise is probably an effect of higher summer temperatures than winter ones. The mean temperature of the Tapes-Littorina Sea was 1–3° C higher than to-day. Northeastern Ireland was warmer than now by about 1.7° C, Bohemia and Central Germany by 2.3–2.6° C, Denmark by 1.5–2° C in the summer months[26]). It seems that the estimate made by F. Firbas[27]), 1.5–2.4° C higher temperature of the vegetative period than now in Central Europe, is very close to the real values.

2. The temperature of Würm glacial (70,000–10,000 years B. P.). The majority of Quaternary temperature estimates, quite naturally, refer to the last glacial stage. However, the differences in the estimates of the temperature drop during the last glacial stage vary between 3–4° C (the lowest limit) and 10–12° C (upper limit). It is interesting to know that most recent estimates are very high, not rarely even more than 12° C[28-35]). The temperature inversion in winter is responsible for such strong cooling in the lower strata of the troposphere[36]). In accordance with recent estimates, we supposed that the drop of temperature in Central Europe in the maximum of the Würm glacial was about 12° C[37-39]). Considering the geographical distribution of certain species, many authors[40]), especially A. Dubois[41]), concluded that the Würm glacial was the coldest episode of the Quaternary period[42-44]).

It remains to note the fact that the minimum temperature was not attained in the middle of the Würm glacial, but closer to its end. (The minimum was about 20,000–22,000 years B. P.) The temperature curve of the Würm glacial – like the temperature curves of all other older glacial stages – was not a symmetrical, but an asymmetrical one. The relation between the phase of the expansion (about 48,000 years in the case of the Würm glacial) and the phase of the recession (about 12,000 years) is 4 : 1. This relation is always the same, regardless of the duration and the age of the glacial stage.

3. The temperature of Riss-Würm interglacial. Riss-Würm interglacial lasted about 40,000 years (70,000–110,000 years B. P.). It is general-

[23]) Ericson et al.: Op. cit., 735.

[24]) Ericson et al.: Op. cit., 737.

[25]) Emiliani, C.: Cenozoic Climatic Changes as Indicated by the Stratigraphy and Chronology of Deep-Sea Cores of Globigerina-Ooze Facies, Annals of the New York Academy of Sciences, Vol. 95, Art. 1, New York 1961, 524.

[26]) See the detailed review in Charlesworth, J. K.: The Quaternary Era I–II, London 1957, 1303, 1411, 1483, 1493.

[27]) Firbas, F.: Spät- und nacheiszeitliche Waldgeschichte Mitteleuropas nördlich der Alpen I, Jena 1949, 61.

[28]) Soergel, W.: Die eiszeitliche Temperaturniedrigung in Mitteleuropa, Jahresber. u. Mitt. des Oberrhein. geol. Ver. 31, 1942, 59: 13,5° C.

[29]) Büdel, J.: Die Gliederung der Würmkaltzeit, Würzburger geographische Arbeiten H. 8, 1960, 21: 14° C.

[30]) Prošek, F. & Ložek, V.: Stratigraphische Übersicht des tschechoslowakischen Quartärs, Eiszeitalter und Gegenwart 8, 1957, 51: 10° C.

[31]) Emiliani, C.: Op. cit. (25), 526: The amplitude in the Mediterranean Sea was 12° C.

[32]) Poser, H.: Auftauftiefe und Frostzerrung im Boden Mitteleuropas während der Würm-Eiszeit, Naturwissenschaften 34, 1947, 232: about 15° C.

[33]) Kaiser, K.: Klimazeugen des periglazialen Dauerfrostbodens in Mittel- und Westeuropa, Eiszeitalter und Gegenwart 11, 1960, 121: 15–16° C.

[34]) Shotton, F. W.: The Physical Background of Britain in the Pleistocene, The Advancement of Science 19, 1962, No. 79, 201: 12,5° C.

[35]) Weischet, W.: Die gegenwärtige Kenntnis vom Klima in Mitteleuropa beim Maximum der letzten Vereisung, Mitt. geogr. Gesell. München 39, 1954, 112: The July temperature was lower than the present by 10–12° C; the winter temperatures were lower by at least 16° C.

[36]) Mortensen, H.: Heutiger Firnrückgang und Eiszeitklima, Erdkunde 6, 1952, 156.

[37]) Flohn, H.: Allgemeine atmosphärische Zirkulation und Paläoklimatologie, Geologische Rundschau 40, 1, 1952, 170: 8–12° C.

[38]) Flohn, H.: Studien über die atmosphärischen Zirkulationen in der letzten Eiszeit, Erdkunde 7, 1953, 270: 13° C.

[39]) Woldstedt, P.: Eine neue Kurve der Würm-Eiszeit, Eiszeitalter und Gegenwart 9, 1958, 151: 12° C.

[40]) For detailed historical review see: Charlesworth, J. K.: Op. cit., 1031.

[41]) Dubois, A. & Stehlin, H. G.: La grotte de Cotencher, station moustérienne, Mém. Soc. Paléont. Suisse II, Vol. 53, 1933, 263.

[42]) Pidopličko, I. G.: Kratkie itogi izučenija pozvonočnyh iz antropogenovyh (četvertičnyh) otloženij Ukrainy, Četvertičnyj period 13, 14, 15, Kiev 1961, 264: Würm maximum was the coldest phase of the Ukrainian Pleistocene.

[43]) Brandtner, F.: Lößstratigraphie und paläolithische Kulturabfolge in Niederösterreich und in den angrenzenden Gebieten, Eiszeitalter und Gegenwart 7, 1956, 128: The Würm maximum was the coldest phase of the Pleistocene.

[44]) Emiliani, C.: Op. cit. (2), 270.

ly believed that the temperature in the thermal optimum of this interglacial stage was not only higher than to-day, but – after some authors – even higher than in the maximum of Hypsithermal time. In Central Europe flourished plants like *Brasenia purpurea, Vitis silvestris, Juglans regia, Aldrovanda vesiculosa, Trapa natans, Naias flexilis, N. marina, Dulichium spathaceum,* most of which to-day do not live in this region. Well-known detailed investigations made by K. Jessen and V. Milthers [45]) and inferred temperatures 2° C higher than now in Denmark and northwestern Germany were confirmed in some other parts of the world. Some authors have assigned to this interglacial stage a classical interglacial sequence with *Rhododendron ponticum* and other species (Hötting, Pianico, Ré, Noronco, Barraux) [46]) some of which are distinctly southern and do not now live in the Alps; the implied former mean annual temperature was warmer than the present by at least 2° C [47]).

In the North Sea Basin (Eem-Sea), which was warmer than to-day, lived numerous representatives of so-called Lusitanian fauna which comprised several species now living in the Mediterranean and off the coast of Portugal and France (e.g. *Tapes aureus* var. *eemiensis, Gastrana fragilis, Lucina divaricata, Mytilus lineatus, Haminea navicula, Syndesmya ovata, Turritella communis, Eulimella nitidissima).* At the same time in the Mediterranean Sea lived some species which to-day do not live in this sea, or – in the majority cases – now thrive only off the Moroccan coast or even in much lower latitudes (e.g. *Strombus bubonius, Conus testudinarius, Mytilus senegalensis, Natica lactea, Bittium Deshajesi, Eastonia rugosa)* [48]). The molluscan fauna in the Netherlands lived in a warmer sea with temperatures 2° C higher than at present [49]). During the last interglacial stage there lived in England and Central Europe a pond tortoise *Emys orbicularis* indicating a mean July temperature 2–3° C higher than to-day [50]). To the Eemian interglacial belongs a typical molluscan fauna from Czechoslovakia *(Helicigona banatica, Soosia diodonta, Gastrocopta theeli, Aegopis verticillus, Cepaea nemoralis, Laciniaria stabilis, Pagodulina pagodula,* etc.) which lived in a climate 2–3° C warmer than now [51-52]), or even 2–4° C warmer than to-day [53]). The "islands" of fossil chernozem found nowadays in dry localities of Central Europe were steppe islands which developed under a warmer climate than to-day. From south-west Germany westwards, in France particularly, and also in the Thames valley, the soils of the Riss-Würm interglacial has a colour more reddish (it has been called "argile rouge") than that of ordinary brown-earth. This can only mean that the climate of West Europe had e tendency towards the Mediterranean climate [54]). Paleopedological investigations in South-east Europe gave the same results; about 2–3° C higher temperatures than now in last three interglacial stages [55]). This was the effect of summers hotter and drier than at present [56]). In the travertines of central Germany have been found *Pinus* cf. *nigra, Quercus* cf. *virgiliana* as south-European forms; this implies a mean July temperature about 2–3° C higher than to-day [57]). The fossils of *Buxus sempervirens, Juglans regia, Thuja occidentalis* and *Quercus Mammuthi* in Bilzingsleben implies, after E. Werth [58]), 1.5–2° C higher mean July temperatures. According to the displacement of the northern boundary of the lime-tree *(Tilia tomentosa),* it was deduced that the mean July temperature at Wallensen was about 3° C higher than now [59]).

The nonexistence of sea ice in the basin of the North Polar Sea in the climatic optimum of the Last interglacial is a generally accepted fact [60]). Considering a hypothetical model of a general atmospheric circulation in the northern hemisphere in the case of nonexistence of sea ice in the North Polar Sea, H. Flohn [61]) arrived at the conclusion that the mean annual temperature would be about 4° C higher than now.

[45]) Jessen, K. & Milthers, V.: Stratigraphical and Palaeontological Studies of the Interglacial Fresh-water Deposits in Jutland and North-west Germany, Danm. geol. Unders. 2, 1928, 353.

[46]) Gams, H.: Neue Beiträge zur Vegetations- und Klimageschichte der nord- und mitteleuropäischen Interglaziale, Experientia 10, 1954, 363.

[47]) Penck, A. & Brückner, E.: Die Alpen im Eiszeitalter, Leipzig 1909, II, 389.

[48]) Gargallo, G.: Reperti malacologici del piano tirreniano nel canale Mussolini, Quaternaria 5, 1958–61, 241.

[49]) Straaten, L. van: Composition of Shell Beds Formed in Tidal Flat Environment in the Netherlands and in the Bay of Arcachon, Geologie en Mijnbouw, N.s. 18, 1956, 225.

[50]) Ullrich, H.: Fossile Sumpfschildkröten *(Emys orbicularis* L.) aus dem Diluvialtravertin von Weimar-Ehringsdorf-Taubach und Tonna (Thür.), Geologie 5, 1956, 360.

[51]) Prošek, F. & Ložek, V.: Stratigraphische Übersicht des tschechoslowakischen Quartärs, Eiszeitalter und Gegenwart 8, 1957, 74.

[52]) Záruba, Q., Kukla, J. & Ložek, V.: Die altpleistozänen Ablagerungen in Žalov bei Prag, Anthropozoikum 10, 1962, 156.

[53]) Ložek, V. & Kukla, J.: Outline of the Stratigraphy of the Czechoslovak Quaternary, Czwartorzęd Europy Środkowey i Wschodniej, t. I, VI Int. Congress INQUA, Warszawa 1961, 164.

[54]) Zeuner, F. E.: The Pleistocene Period, London 1959, 108.

[55]) Jaranoff, D.: Das Klima des Mittelmeergebietes während des Pliozäns und des Quartärs, Geologische Rundschau 34, 1944, H. 7/8 441.

[56]) Marković-Marjanović, J.: Die Bedeutung der fossilen "terra rossa"-Horizonte für die Stratigraphie und Chronologie des Pleistozäns von Jugoslawien, Verh. geol. Bundesanstalt 1960, H. 1, 18.

[57]) Vent, W.: Über die Flora des Riss-Würm-Interglazials in Mitteldeutschland, Wiss. Zschr. Univ. Jena 4, math.-nat. Reihe, H. 4/5, 1955.

[58]) Werth, E.: Die pflanzenführenden Diluvial-Ablagerungen der thüringisch-sächsischen Bucht und ihre pflanzengeschichtliche und klimatologische Bedeutung, Ber. Deutsch. Botan. Gesellschaft 43, 1925, 398.

[59]) Rabien, I.: Die Vegetationsentwicklung des Interglazials von Wallensen in der Hilsmulde, Eiszeitalter und Gegenwart 3, 1953, 125.

[60]) Brooks, C. E. P.: Evolution of Climate, London 1925, 51.

[61]) Flohn, H.: Kontinental-Verschiebungen, Polwanderungen und Vorzeitklimate im Lichte paläomagnetischer Meßergebnisse, Naturwiss. R. 12, 1959, 384.

4. The temperature of Riss glacial. The Riss glacial lasted 72,000 years (110,000–182,000 years B. P.). In accordance with natural laws one must to suppose that the mechanism of the development of the ice sheets in the northern hemisphere was in essence similar to those in the Würm glacial. One may suppose that the Riss glacial was characterised by many stadials and interstadials. The extent of the Rissian ice sheets leads to the conclusion that the temperature drop must have been of the same order of magnitude as that during the Würm glacial. F. W. SHOTTON [62]) estimated the drop of temperature in Britain at 9° C at least, but he is convinced that it was even greater.

The loess of the Seine Basin is clearly subdivided in 3 horizons [63]). Rissian loees was rarely discovered; in the vicinity of Brno (Moravia) loess profiles are subdivided into a few loess and fossil soil horizons [64]). The detailed faunistic analysis revealed that the Rissian loess in Central Europe was accumulated in a climate with strong maritime influence, contrary to the Würmian loess which was accumulated in a markedly continental climate, i. e. the climate of the Riss glacial was somewhat warmer than the climate of the Würm glacial [65]), in spite of the greater extent of the ice sheets during the Riss glacial.

5. Temperature of the Mindel-Riss interglacial. Due to its very long duration, this interglacial stage is called the "great interglacial". The reason for such a long duration was a nonexistence of thermal isolation of the Arctic Basin a little time after the middle of the great interglacial when a new glacial stage must have to come into existence. The analysis of one deep-sea core consisting of sediments which were precipitated under the direct influence of the Antarctic ire sheet [66]) reveals that in the middle of the great interglacial the interglacial sedimentation was twice interrupted by glacial sedimentation; this means that the great interglacial in Antarctic was not a continuous, long, uninterrupted interglacial. The lithology of core samples from the Ross Sea allows us to draw the conclusion that the Antarctic ice sheet expanded during the great interglacial. This was a real glacial stage, but we must bear in mind the mechanism of the Antarctic pulsation (no fundamental changes in the area of the Antarctic ice sheet in glacial stages in comparison with its area in interglacial stages [67]). At the same time in the northern hemisphere, instead of the glacial stage which had come into existence, the post-Mindelian interglacial stage was prolonged in an unusually long interglacial stage (according to our calculation, the great interglacial stage lasted 192,000 years, i. e. 182,000–374,000 years B. P.). The glacial stage on the Antarctic had no equivalent in the northern hemisphere because the North Polar Sea was not thermally isolated. The thermal influence of the Antarctic glacial stage plus the influence of the expanding Greenland ice sheet and the sea ice in the North Polar Sea a little after the middle of the great interglacial were represented as a relatively slight temperature drop [68]).

The above-mentioned high temperature of the great interglacial was clearly established in one Pacific Ocean core sample [69]). Calcium carbonate abounds much more in the sediments belonging to the great interglacial than in the Riss-Würm sediments; this is, probably, a result of warmer water in the great interglacial than in the Riss-Würm interglacial.

The Tertiary relics *Tsuga, Zelkova, Carya, Pterocarya*, imply a slightly higher temperature in the great interglacial than in the R/W interglacial in which there are no traces of this species [70]). In some localities are found *Buxus sempervirens, Azolla filiculoides, Vitis silvestris, etc.* [71]) implying high temperatures, at least in certain periods. The Cannstadt fossil flora is very similar to the recent Colchic flora and this proves that in the climatic optimum of this interglacial the temperature was 2–3° C higher than to-day [72]). A fossil flora in the Lublin area with *Vitis silvestris* Gmel. implies that the temperature was at least 2° C higher than now [73]). During the thermal optimum of this interglacial stage in Ireland there grew *Abies, Picea* and *Rhododendron*, denoting a climate a little warmer than during Hypsithermal time [74]). The pollen curves of *Pinus* and *Betula* in pollen diagrams from Central Europe denote a cooler phase in the great interglacial [75]); this was proved by many paleobotanic investigations in Poland [76]).

The high temperature of the Mediterranean Sea water is confirmed by the occurrence of a warm and quite distinctive fauna (M. GIGNOUX 1913) [77]) with *Strombus bubonius, Mathilda canariensis, Tritonium ficoides, Cardita senegalensis, Mytilus senegalensis, Conus guinäicus, Natica lactea* and other species with tropical affinities, which to-day find their northern limit off the Senegal coast or are restricted to the warmest part of the Mediterranean Sea. The shells *Lutraria rugosa* and *Pecten polymorphus*, the representatives of

[62]) SHOTTON, F. W.: Op. cit. (34), 198.

[63]) Quoted by WOLDSTEDT, P.: Das Eiszeitalter. Grundlinien einer Geologie des Quartärs II, Stuttgart 1958, 282.

[64]) PELÍŠEK, J.: Kvartér východního okolí Brna, Anthropozoikum 3, 1953, 27.

[65]) BRANDTNER, F.: Op. cit. (43), 128.

[66]) HOUGH, J. L.: Pleistocene Lithology of Antarctic Ocean-bottom Sediments, J. Geology 58, 1950, 257.

[67]) FLINT, R. F.: Glacial and Pleistocene Geology, New York 1957, 52: The formerly glacier-covered area in the Antarctic Continent was less than 13% greater than existing glacier areas.

[68]) ŠEGOTA, T.: Op. cit. (4), 91.

[69]) HOUGH, J.: Pleistocene Climatic Record in a Pacific Ocean Core Sample, J. Geology 61, 1953, 260.

[70]) GAMS, H.: Op. cit. (46), 358.

[71]) WOLDSTEDT, P.: Op. cit. (63), 19 and 64.

[72]) BERTSCH, K.: Die diluviale Flora des Cannstatter Sauerwasserkalks, Z. Botanik 19, 1927, 654.

[73]) SOBOLEWSKA, M.: Dzika winorośl *(Vitis silvestris* Gmel.) w plejstocenie polskim, Z badań czwartorzędu w Polsce, t. 5, Warszawa 1954, 166.

[74]) WATTS,. W. A.: Interglacial Deposits at Kilbeg and Newtown, Co. Waterford, Proceedings of the Royal Irish Academy, B 2, Vol. 60, Dublin 1959, 127.

[75]) WOLDSTEDT, P.: Op. cit. (63), B. I, 229.

[76]) ŚRODOŃ, A.: Flory pleystoceńskie z Tarzymiechów nad Wieprzem, Z badań czwartorzędu w Polsce, t. 5, Warszawa 1954, 75.

[77]) CHARLESWORTH, J. K.: Op. cit. (26), 1256.

the warm Tyrrhenian in Britain, no longer thrive north of Madeira and Portugal [78]). Of tle same age are the Paludina Beds in the Berlin area with thermophile fresh-water molluscs *(Paludina diluviana* etc.).

In the vicinity of Prague, chernozem strata separated by a layer of loess which was precipitated under cool conditions of climate belonging to the great interglacial. The occurrence of *Helix pomatia* L., *Fruticicola fruticum* Müll., *Celtis* sp. in Moravia denote a strong influence of the Mediterranean climate [79]).

The long duration and high temperature of the great interglacial were also confirmed by paleopedologic investigations in Yugoslavia. The mean thickness of terra rossa in the Riss-Mindel interglacial in continental Yugoslavia is about 2 m, but that of the great interglacial amounts to 6–7 m. Besides this, the red colour of soil belonging to the great interglacial is much more intense than the colour of the younger terra rossa [80]).

6. Temperature of the Mindel glacial and older "glacial stages". As early as 1879 A. Penck [81]) proved in Northern Germany three glacial stages; the existence of a fourth glacial stage was never confirmed. More and more data undoubtedly prove that first glacial stage in the northern hemisphere was the Mindel glacial. There are no traces of the existence of great continental ice sheets in the northern hemisphere prior to the Mindel glacial [82-83]). The temperature drop before the Mindel glacial cannot be compared with the cooling of the climate in the Mindel and post-Mindel glacials [84-85]). Relatively slight cooling in pre-Mindelian times resulted only in stronger mountain glaciations (in the Alps and elsewhere). The transition from the Pliocene to the Pleistocene was marked by at least 3 cool phases [86]). Each older pre-Mindel "glacial phase" was less cold than the younger one [87]). The invasion of Mediterranean waters by "northern guests" *(Cyprina islandica, Mya truncata, Natica montacuti, Trophon muricatus, Buccinum undatum, B. humphreysianum,* etc.) was much more intense in the Sicilian than in the Calabrian. The evidence to-day certainly does not substantiate the argument that climatic conditions in Italy during Sicilian times were markedly cooler than those of the present day [88]).

Impoverishment of flora and fauna, both terrestrial and marine, and a gradual replacement of Tertiary forms by modern species (many examples with detailed numerical data one can find in all standard handbooks) was a longlasting process and not a rapid one, as it must have been if the pre-Mindel phases had been the glacials. The Villafranchian fauna, which resembles the preceding Pliocene fauna in many ways, disappeared toward the end of the Mindel glacial. At that time, extinctions and introductions were so numerous that a new fauna can be said to have come into existence. It implies distinctly cooler climates than those of Villafranchian time, and it inclused a number of "glacial" elements [89]). Climatic differentiation of the fauna was much more pronounced in the younger than in the older Pleistocene [90]). Similarly the gradual extinction of thermophile forms from the flora was markedly accelerated in two phases, one of which was caused by the expansion of the Mindel ice sheets [91-93]).

The only numerical data about the climate of the end of Pliocene and the beginning of the Pleistocene in Central Europe are given in well-known papers by W. Szafer which are based chiefly on the pollen and macroflora of nonglacial sediments in Carpathian Poland. From his diagram [94]) it is clearly evident that the Günz temperature drop was not of the same order of magnitude as those of the post-Günz glacial stages; the comparison ist not possible [95]). This was proved by W. Szafer [96]) even in 1954. He implies that the mean annual temperature during the Mindel maximum was — 5° C, while in the maximum of the Günz glacial the mean annual temperature was 5° C ("cold, though not arctic climate"). Accordingly, the difference was 10° C! Such a great difference would never have been possible if Günz had been a true glacial stage, i. e. if huge continental ice sheets had existed (as in all post-Günz glacials).

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[78]) Charlesworth, J. K.: Op. cit. (26), 1257.

[79]) Prošek, F. & Ložek, V.: Op. cit. (30), 73.

[80]) Marković-Marjanović, J.: Op. cit. (56), 18.

[81]) Penck, A.: Die Geschiebeformation Norddeutschlands, Z. deutsch. geol. Ges. 31, 1879, 195.

[82]) Zeuner, F. E.: Op. cit. (54), 315: The second phase of the Antepenultimate Glaciation was the first intense glacial period.

[83]) Kurtén, B.: Chronology and Faunal Evolution of the Earlier European Glaciations, Soc. sci. Fennica, Comm. Biologicae 21, 1960, No. 5,27: Elster II is the first realy great ice age.

[84]) Vlerk, I. M. van der: The Significance of Interglacials for the Stratigraphy of the Pleistocene, Quaternaria 2, 1955, 38: It is quite possible that during the first half of the Pleistocene the temperature of cold times was not yet of such a natura that we may speak of real glacial time.

[85]) Altehenger, P. A.: Klimaschwankungen im Pliozän von Wallensen (Hils), Eiszeitalter und Gegenwart 9, 1958, 104: Pliocene temperature oscillations can be compared with those of the Pleistocene, although the latter ones, at least since the Günz glaciation, were by far of stronger intensity than those of the Pliocene.

[86]) Zeuner, F. E.: Op. cit. (54), 79.

[87]) Woldstedt, P.: Op. cit. (75), I, 245.

[88]) Movius, H. L.: Villafranchian Stratigraphy in Southern and Southwestern Europe, J. Geology 57, 1949, 393.

[89]) Flint, R. F.: Op. cit. (67), 450.

[90]) Woldstedt, P.: Op. cit. (63), 220.

[91]) Gričuk, V. P.: Stratigrafičeskoe rasčlanenie plejstocena na osnovanii paleobotaničeskih materialov. Hronologija i klimaty četv. perioda, Moskva 1960, 27.

[92]) Gričuk, V. P.: Iskopaemye flory kak paleontologičeskaja osnova stratigrafii četvertičnyh otloženij, Relef i stratigrafija četv. otlož. Severo-zap. Russkoj ravniny, Moskva 1961, 25.

[93]) Rein, U.: Pollenanalytische Untersuchungen zur Pliozän-Pleistozängrenze am linken Niederrhein, Geologisches Jahrbuch 65, 1949 (1951), 773.

[94]) Szafer, W.: Op. cit. (16), 127, fig. 6.

[95]) Müller-Beck, H.: Paläolithische Kulturen und Pleistozäne Stratigraphie in Süddeutschland, Eiszeitalter und Gegenwart 8, 1957, fig. 5 (p. 137). On a schematic temperature curve it is represented that during the Donau maximum the climate was subarctic, i.e. much warmer than in Riss and Würm glacials.

[96]) Szafer, W.: Op. cit. (15), fig. 3.

The nonexistence of both the ice sheets and of a marked temperature drop in the older part of the Pleistocene can be seen very clearly from the fact that in the first pre-Günz cool phase (the transition from Mizerna I to Mizerna I/II, after R. F. FLINT [97]), the equivalent to the Alpine Donau "glacial") the mean annual temperature was about 7° C, accordingly, only 2° C more than in the Günz glacial.

The accuracy of the above-mentioned paleotemperature data is confirmed by paleotemperature investigations in the Central Plateau of France. By the analysis of a fossil flora which belongs to a certain cooler phase, A. LAUBY (1910) proved [98]) that the mean annual temperature was approximately 10° C, or 2° C lower than the present mean. The accurate age of this flora is not known, but by comparison with SZAFER's paleotemperature curve one may conclude that this temperature is of the same order of magnitude as the temperature of the Günz and Donau "glacials" (taking into consideration the fact that southern France is somewhat warmer than Carpathian Poland). H. MOVIUS [99]), like the majority of other authors, considers that Villafranchian is synchronous with Günz "glacial", and the above-mentioned figures would refer to Günz "glacial".

That the temperature changes (the temperature range) in the beginning of the Pleistocene and at the end of the Pliocene have been smaller than in post-Günz time was proved by the analysis of the rate of low latitude atmospheric circulation in the equatorial Pacific [100]), and by isotopic analysis of Formaminifera in the Mediterranean [101]). Isotopic temperatures obtained by the analysis of Sicilian Foraminifera (probably of Günz age) denote considerably higher temperatures than those of the younger glacial stages. Shortly, the evidence to-day certainly does not substantiate the argument that climatic conditions in Italy during Sicilian times were markedly cooler than those of the present day [102]).

7. Temperature of the Günz-Mindel and older "interglacial stages". Our paleotemperature curve was constructed on certain premises; one of them is GAMS' assertion [103]) that Mindel was the first Pleistocene glacial stage in the full sense of the word. In this case, all relatively cooler or warmer periods to the Mindel glacial have to be called cool stages or warm stages respectively, and not glacials and interglacials.

Our paleotemperature curve which belongs to the older part of the Pleistocene is based mainly on W. SZAFER's investigations. He implies that during the climatic optimum of the Günz-Mindel warm stage in Carpathian Poland [104]) the mean annual temperature was 8° C. In the maximum of the first pre-Günz warm stage (Mizerna II) the mean annual temperature was 13° C. The temperature in the pre-Mindel cool stages had become slightly cooler in every succesively younger cool stage (more and more unfavourable for organic life). Ample literature confirms the progressive impoverishment of land and sea flora and fauna in each succesive younger warm stage. In each succesive warm stage species which could not survive the cold of the preceeding cool stage disappeared; the "victims" always have been the thermophile species. One fact may be regarded as established, namely that the climate of Günz-Mindel at its optimum was considerably warmer than that of all the next interglacials [105]).

G. DEPAPE (1928) has calculated [106]) that during Upper Pliocene times the layers of the Saône region were accumulated during a period when the climate in the basin averaged some 5.5 or 6° C warmer than it does at present.

Successively lower temperatures of the cool and warm stages, as well as of the temperature of glacials and interglacials, was confirmed by paleopedologic investigations in the Pyrenees [107]) (laterisation until the end of the Pliocene; the formation of terra rossa in warm stages and interglacial stages, of brown earth in Riss-Würm interglacial, and of podsol in Holocene). A similar situation existed in all of Mediterranea Europe and even in some parts of Central Europe, which, during interglacial stages, was under strong influence of the Mediterranean climate. In Czechoslovakia it has been proved that the youngest allitic terra rossa dates from the end of the Tertiary and from the lowest Quaternary. Terra fusca soils are typical of the Early and Middle Pleistocene. It can be inferred that siallitic terra rossa continued to form in karst cavities even in warm periods of the earliest Pleistocene. Thin layers of terra fusca have been observed also on travertines of the last interglacial stage [108-109]). High temperature was a prerequisite for the development of broad corrosive surfaces on the limestones in the karst region of Yugoslavia in the Upper Pliocene [110]).

97) FLINT, R. F.: Op. cit. (67), 398.

98) Quoted by WOLDSTEDT, P.: Op. cit. (63), 278.

99) MOVIUS, H. L.: Op. cit. (88), 402.

100) ARRHENIUS, G.: Op. cit. (21).

101) EMILIANI, C., GIANOTTI, A. & MAYEDA, T.: Analisi isotopica dei foraminiferi Siciliani delle argille di Ficarazzi, Palermo, Quaternaria V, 1958–61, 141.

102) MOVIUS, H. L.: Op. cit. (88), 393.

103) GAMS, H.: Die Abgrenzung des Quartärs, Zeitschrift für Gletscherkunde und Glazialgeologie 2, 1952, 158.

104) W. SZAFER's correlation (Tegelen = Günz/Mindel) is omitted as being inappropriate, because the Telegen sediments in the Netherlands occupy a lower stratigraphic position.

105) SZAFER, W.: Op. cit. (15), 213.

106) Quoted by MOVIUS, H. L.: Op. cit. (88), 394.

107) ALIMEN, H.: Colorimétrie des sédiments quaternaires et paléoclimats. Premiers résultats, Bull. Soc. Géolog. France 6, 1954, 614.

108) KUKLA, J. & LOŽEK, V.: Soils, Czwartorzęd Europy Środkowej i Wschodniej, t. I, VIth Int. Congress of INQUA, Warszawa 1961, 61.

109) SMOLÍKOVÁ, L. & LOŽEK, V.: Zur Altersfrage der mitteleuropäischen Terrae calcis, Eiszeitalter und Gegenwart 13, 1962, 172.

110) ROGLIĆ, J.: Zaravni na vapnencima, Geografski glasnik 19, Zagreb 1957, 131 (in Croatian language with French summary).

THE CITY OF KERMAN, IRAN *)

With 3 figures and 1 table

PHILIP BECKETT

Zusammenfassung: Die Stadt Kerman im Iran

Die Stadt Kerman liegt im südlichen Teil des Iran in einem weiten Gebirgskessel mit einer größeren Anzahl landwirtschaftlicher Niederlassungen. Stadt und Dörfer wurden getrennt untersucht.

Die Stadt ist jetzt Provinzhauptstadt und war seit mehreren Jahrhunderten ein Zentrum für Handel, Industrie und Verwaltung. Ihre unmittelbare Umgebung jedoch ist weniger für den Lebensunterhalt einer hohen Bevölkerungszahl geeignet als die verschiedener anderer Städte des südlichen Iran. Kerman im besonderen ist abhängig vom Wasser, das aus einer Entfernung von 30 km durch kostspielige Untergrundkanäle (qanat) bezogen wird, die zwischen 10 und 300 m unter der Oberfläche verlaufen.

Die vorliegende Arbeit beschäftigt sich mit der Geschichte und dem Handel der Stadt Kerman und zeigt, wie die p o l i t i s c h e n und k o m m e r z i e l l e n Vorteile ihrer Lage die natürlichen Nachteile überwogen haben. Diese Vorteile lassen sich beide von der Tatsache herleiten, daß Kerman weiter als seine möglichen Rivalen von den Gebieten der primitiven Stämme im Süden und Westen entfernt ist und damit weniger deren Zugriff ausgesetzt war.

Als Gegenstück wird in einer zweiten Arbeit (BECKETT und GORDON) gezeigt, wie die landwirtschaftlichen Niederlassungen im Kerman-Kessel, ihre Landnutzung und die Beschäftigungsarten der Bewohner fast gänzlich von den Faktoren der n a t ü r l i c h e n Umgebung bestimmt werden.

Der Vergleich beider Arbeiten läßt deutlich hervortreten, wie im selben Gebiet die Bedeutung der verschiedenen kausalen Faktoren (der natürlichen politischen und kommerziellen Vorteile usw.), für die Entwicklung menschlicher Niederlassungen verschiedener Größe sehr unterschiedlich sein kann.

Introduction

An earlier paper (BECKETT and GORDON) has described the rural settlements round Kerman in southern Iran. Their distribution appears to be almost wholly explicable in terms of the local physical environment, and notably *water* and *soil*. Not only the distribution of population but also their occupations, and the pattern of land use, depend upon the balance of soil and water.

The present paper discusses the city of Kerman itself of which, in contrast, the location and development seem to be inexplicable except in terms of political and economic factors.

The City of Kerman

The city of Kerman is high and dry. It lies about 5.600 ft. above sea level, and experiences an average annual precipitation of 15 cms. The winters are bitterly cold. The summers are hot, but the relative humidity is moderate.

Until recently Kerman has been isolatd from neighbouring centres by tedious and intermittently dangerous journeys. Camel caravans used to take 30–40 days to reach Shiraz, 25–40 days to Bandar Abbas, and 25–30 days to Yezd (see Fig. 1.). Not infrequently,

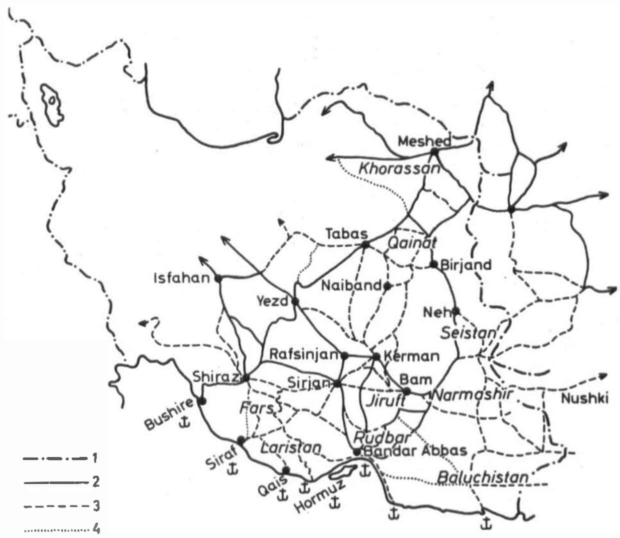

Fig. 1: Caravan routes of South and East Iran.
1 current international boundaries; 2 preferred routes capable of supporting substantial caravan traffic; 3 other routes preferred during some periods but less capable of carrying substantial traffic; 4 uncertain routes
(Compiled from various sources)

tribal lawlessness in Fars, Laristan or Baluchistan closed the roads completely. The published reports from the Bristish Consulate in Kerman early in this century commonly refer to such hindrances to trade [1]), and to the inability of any but the strongest governors to provide sufficient security for the commerce on which Kerman depended. (*4493; 5263; 5452*) [2]).

Tall limestone crags not far from the centre of the Kerman plain provide the kernel for a strong defensive position. They were presumably the nucleus round which the city has developed. The complicated geological folding, that produced the crags, has apparently also given rise to a relatively shallow ground water table near their foot. Numbers of qanats (BECKETT 1953; NOEL 1944; SMITH & ARMSTRONG 1951) tap the ground water immediately to the north, east and south of the city. Yet the water resources of the immediate neighbourhood are quite unable to support the present (1956) population of 62.160, and populations comparable, or up to 100.000, during

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[1]) e.g. "Roads are impassable except for well-armed parties able to beat off attack". (1908/09; *4316*). Such lawlessness is reported in 1902/3 (*3182*); 1907/8 (*4162; 4156*); 1908/9 (*4376; 4396*); 1910/11 (*4702; 4838; 5263*); 1912/13 (*5211; 5266*). For italic numbers see footnote 2.

[2]) Diplomatic and Consular Reports are referred to in the text by their serial numbers, in italics.