On the glaciation of South America as related to tectonics : observations 1939-1947

Autor(en): **Heim, Arnold**

Objekttyp: **Article**

Zeitschrift: **Eclogae Geologicae Helvetiae**

Band (Jahr): **44 (1951)**

Heft 1

PDF erstellt am: **24.09.2024**

Persistenter Link: https://doi.org/10.5169/seals-161435

On the
Glaciation of South America as related to Tectonics
Observations 1939—1947

By **Arnold Heim**

With 3 figures

Content

Introduction

The present paper has been presented to the XVIIIth International Geological Congress, held in August 1948 in London, and was accepted by the Editorial Board (See Abstracts published for the Congress). Unfortunately, for financial reasons, it was decided in November 1950 that only one paper of each author could be printed in full under Part XIII. Thus, with the expression of regret, the manuscript was returned to the author.

The observations in this report are mainly based on the authors private travels during the years 1939 to 1947. Part of the observations have been published in Spanish, English and German, though no general review was presented on the relation of the galciation with the vertical tectonical movements of the Andes. The following voyages were made:

1) October 1939–March 1940: Chilean Switzerland (Lake district of Southern Chile) and Southern Patagonia, crossing the Andes from Puerto Aysen to E (Argentine Pampa), thence penetrating eastward on Lago Buenos Aires to the Inland Ice of San Valentin region (45–47° S). Heim, Arn., 1940.

2) Jan.–March 1944: Atlantic coast from Comodoro Rivadávia–Rio Gallegos through Magallan Strait and Fjord channels to Puerto Montt and Valdivia in Chile. Therefrom crossing the southern Andes via Lago Todos los Santos to Bariloche in Argentina.

3) April–June 1944: Geological studies of Precordillera and High Cordillera of Dep. San Juan, northern Argentina. Carboniferous, Pleistocene and Present glaciations (HEIM ARN., 1945, 1946 c).

4) March–May 1945: High Cordillera of San Juan, N-side of Aconcagua and Mercedario.

5) October 1945: Carboniferous glaciation of Precordillera de San Juan (HEIM ARN., 1945, 1946 c, 1948 b).

6) Nov. 1945–Jan. 1946: Leading second Swiss expedition to the Inland Ice of San Valentin, Patagonia (HEIM ARN., 1946 a).

7) Feb.–March 1946: Glacial studies in Argentine Patagonia, Lago Argentino and Viedma (HEIM ARN., 1946 b).

8) April–May 1946: Bolivia, Cordillera Real and Volcano Sajama.

9) June–July 1946: Cordilleras of Peru, E and W of Huancayo (HEIM ARN., 1947 a—b, 1948 d).

10) August 1946: Crossing the glaciated eastern Cordillera of Peru, Cerro Salcantay (HEIM ARN., 1948 c and d).

11) Dec. 1946–Jan. 1947: Catamarca–Paso San Francisco (Argentina–Chile); highest volcanoes of Earth.

12) June 1947: SE-Cordillera of southern Peru, Apolobamba–Ananea (HEIM ARN., 1948 d).

13) July–Aug. 1947: Cordillera of Huayhuash and Cordillera Blanca, highest of Peru and of Tropics in general (HEIM ARN., 1947 c, 1948 d).

* * *

Besides these ground travels, several flights in Peru were made up to 7000 metres in order to obtain general views and photographs of the highest glaciated ranges. They illustrate specially the desglaciation in recent years (HEIM ARN., 1948 d).

Magallanes Strait and the Patagonian Fjords

The first impression of the geological visitor of the southernmost Andes is the enormous difference between the end of the actual glaciers as compared with the Pleistocene moraines. This is illustrated in the fundamental work of CALDENIUS in 1932. Practically all of the southernmost part of South America and of the island of Tierra del Fuego was covered with ice. It also occupied the greater part of the actual fjord region of the Pacific side, where only the higher part of the peninsulas and of the greater islands emerged of the ice. This is seen by the difference between the smoothed lower parts and the rugged surface of the big island of Taitao which formed a nunatak. These facts are plainly explained by a *general tectonical subsidence.* The main reasons are deducted from the following observations:

1. The continental ice-sheet during all pleistocene time was situated far off the west of the present ice- and water-shed. It ran to a large extent over the present sea channels as already shown by CALDENIUS (1932, map, pl. 42).

2. The intricate network of channels and islands shows the forms of a drowned mountain region, modelled by pre- and interglacial river erosion. The longitudinal channels parallel to the general trend of the Andes and of the ocean border cannot have been excavated by ice erosion, being at right angles to the general ice flow.

3. The nautical maps show extraordinary depths in the inner part of the fjords as compared with their outlet to the ocean. For Baker Channel, BRÜGGEN (1934) mentions a depth of 1400 m, while the general shelf border is not deeper than a few hundred metres.

Towards the northern end of the fjord region, the gulf of Ancud shows a wide depression of the sea bottom. Its depth exceeds that of its surroundings by 200 metres. BRÜGGEN explains these overdeeps by glacial erosion. In my view, they are not caused by glacial erosion, but by various other ways. In the first place, they may have been formed behind the end moraines by melting of ice tongues in situe without any gradual retrocession. The surroundings of the dead ice would have been filled with washed moraine material, aided by the influence of strong tidal currents.

The subwater thresholds of the fjords at their outlet into the Pacific may be mainly caused by drowned terminal moraines. In addition to this so-called "Übertiefung", local tectonical trough-like subsidence may have been added to the general subsidence in the prolongation of the tectonical depression of the chilean longitudinal depression, which ends on the surface at Puerto Montt, but continues further south.

A detailed morphological study of the submarine and the surface topography of the patagonian fjord region would be of the highest general interest.

Supposing that the region of Lago Buenos Aires on the E-side of the Andes would be drowned a few hundred metres, a fjord would be formed with its deepest part near the head behind the end moraine. Also the other lakes, like L. Argentino would become manyfold branched fjords of similar appearance as those on the pacific side.

4. The subsidence is actually going on as demonstrated for instance by the drowned forests of Lago San Rafael and Estuario Elefantes (46–47° S).

5. The general subsidence of the Pacific side of the patagonian Andes is further demonstrated by the reversed flow of the rivers. Many glacial rivers that flowed eastwards to the Atlantic now run westwards to the Pacific, having cut their way across the highest part of the Andes and across the former ice-shed.

Lago Argentino, 50° S.

The atlantic coast at this latitude and further north around Golfo de San Jorge (Comodoro Rivadávia) is characterized by its elevated mesas of horizontal marine Miocene. At Santa Cruz, the terrace of 250–300 m falls abruptly to the sea. With a cover of Pleistocene gravel it gradually rises westward, as seen on both sides of rio Santa Cruz. First, the slope equals that of the valley bottom, thence the terrace rises more rapidly as far as Cerro Calafate, where it stands at about 800 metres.

The older pleistocene glaciers reached even farther down the valley than supposed by Caldenius. In a well at Puerto Baretto, ground moraine was encountered below fluvioglacial gravel down to the horizontal Miocene at 80 m depth.

Lago Argentino (200 m) is a wide basin behind the terminal Würm-moraines, its fjord-like branches reaching the actual glaciers Moreno, Ameghino, Upsala and others (Feruglio 1944).

Apart from the lake, the old platforms do not rise further towards the Andes. In one case, in the contrary, I observed a slight inclination towards the Cordillera, namely of the Mesa on the SE side of Brazo Rico (HEIM ARN., 1946 b, p. 7). This indicates that we are at the margin between the quarternary tectonical uplift of the atlantic side and the general subsidence towards the Pacific (Pleistocene geanticline).

Special attention has been paid to the wonderful Moreno Glacier. It is one of the few on our globe which at the present time is in a stage of advance. During the last 500 years its maximum extension was in 1942, when it dammed the southern part of the lake as much as 17 metres (HEIM ARN., 1946 b).

Lago Buenos Aires, 46–47° S.

North of Lago Viedma follow the multy-branched Lago S. Martin and L. Pueyrredon. Both have changed their drainage towards the Pacific. The same is the case with the greatest of the South American glacial basins, Lago Buenos Aires (217 m). It extends its waters 150 km into the glaciated mountains. Similar to L. Pueyrredon, a postglacial gorge has been cut trough the crystalline basement of quartz phyllite and granite (HEIM, ARN., 1940, CALDENIUS 1932). In no place of the world have I seen such tremendous masses of terminal moraines as around Lago Buenos Aires. CALDENIUS gives for the end-glacial (Würm) moraines a height of almost 250 metres above the lake and over 400 m on its N and S sides. To the north of the lake end on the road from Nacimiento to Paso Mayo I measured on 3 jounreys a height of the Fini-glacial moraine hills as 800–830 m, or 600 m above the lake!

North and south of Paso Mayo, fluvioglacial mesas extend for hundreds of square kilometres at 600–700 m above sea level. Corresponding old lake terraces I found up to almost 500 m above the present water level of Lago Buenos Aires in its middle part. But in vain I sought for distinct postglacial end moraines until reaching the glacial Lake Leon at 350 m, 150 km inland of the end of Lago Buenos Aires. There, about 8 km off the present glacier which flows down from the Inland Ice and plunges into Lago Leon, two superimposed terminal moraines of retreat were formed at 140 and 30 m above this lake. I have called them the Leon stages.

No still later signs of retreating moraines being found, it is supposed that the basin of Lago Leon has been formed by melting of the ice sheet *in situ* without a gradual retreat of the glacier tongue. Thus the water basin was made by melting of the dead ice.

Up to latitude 42½° S the present watershed of the Andes is situated 20 to 150 km east of the culminating snow mountains. A striking feature is the capture of Lago General Paz. whose outlet Rio Paloma first flows eastward, then is captured and turns to the Pacific.

The last northern reversed river which flows to the Pacific (Rio Yelcho 43° S) drains the waters from as far as 75 km east of the ice-shed.

Northern Patagonia and Chilean Switzerland

We now come to the region of the multi-armed Lago Nahuelhuapi, at 767 m, where the watershed coincidides with the culminating mountains. Here, in latitude 41° S, we find a second culmination of the Andes in the form of the old volcano Tronador 3460 m, whence the glaciers flow down on both sides of the continental watershed. At Casapangue, on the chilean side, the glacier comes down to 370 m above sea level. The westward distance to Puerto Varas, where the Würm end-moraine forms the huge Lake Llanquihue, is 95 km.

The northern continuation of the fjord depression of Patagonia is nicely traced by the beautiful glacier lakes of Chilean Switzerland: Llanquihue (51 m), Rupanco (172 m), Puyehue (212 m), Ranco (70 m), etc., all being dammed by morainic arcs which are regarded as representing the ultimate or Würm glaciation. Beyond these lakes extended the ice of the penultimate (Riss) stage. It completely covered the fertile central valley at Osorno up to about 400 m on the flanc of the Precordillera (Observations of Eng. WALTER MEYER). The general topographic position was strikingly similar to that of the present inland ice sheet of San Valentin.

As far as km 65 on the road from Osorno northward to Valdivia (40° S) we have found ground moraine. This is about 20 km beyond the moraines of the last glaciation, and 125 km W of the Andean watershed. (Fig. 1.)

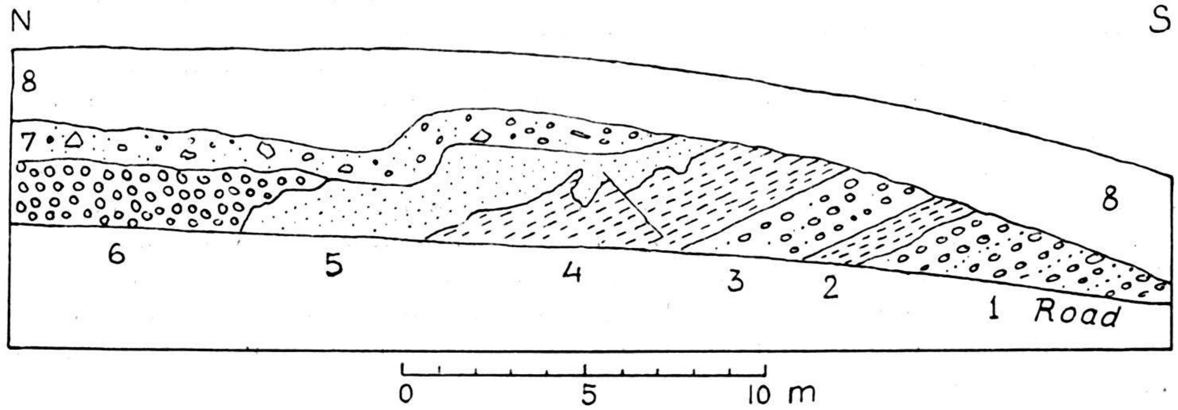

Fig. 1. *Middle Pleistocene at km 65 on road Osorno-Valdivia*
1 = Conglomerate of extrusive rocks; *2* = yellow shaly clay; *3* = like *1*; *4* = like *2*; *5* = whitish volcanic tuff; *6* = conglomerate of andesite, much weathered, with loam as ground mass, non stratified; *7* = much weathered ground moraine (Riss ?); *8* = brown earth, probably decomposed loess.

Older glacial deposits may be expected but are not yet confirmed.

While the estuaries of Valdivia still show some influence of subsidence, the Huasco valley which traverses the main longitudinal depression is a 200 m deep channel, as already observed by Darwin. This apparently represents the erosion since the penultimate glaciation.

The general aspect of Chilean Switzerland around parallel 40° S, with its blue lakes that border the Andes, recalls the border lakes of the Alps which also were formed by terminal moraines and under the influence of vertical tectonical oscillations. The lakes Calafquen and Panguipulli are bordered with very high terminal moraines, and their outlet is turned backward towards the Cordillera (WALTER MEYER).

On the eastern side of the Andes, the Würm glacier extended far beyond lake Nahuelhuapi (767 m) into the Argentine Pampa. To the north-east, 15 km N of Jonas Ranch, the river Limay flowing out of the lake has cut an epigenetic gorge across Tertiary igneous rocks, leaving to its left an interglacial valley filled with gravel and moraine up to about 60 m above the river (Fig. 2). This locality is situated 70 km E of the Andean watershed.

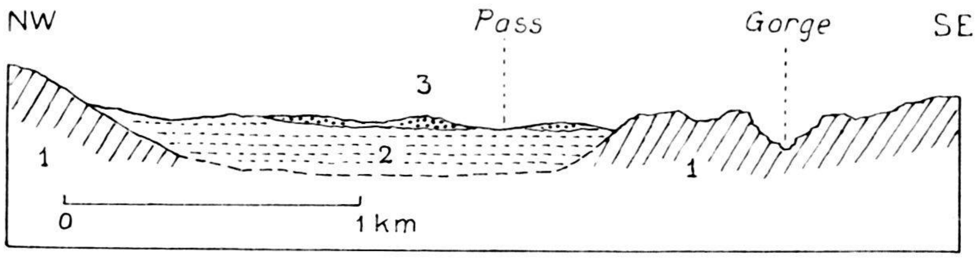

Fig. 2. *Cross-section of Limay Valley showing interglacial gravel capped with moraine* *1* = Tertiary igneous rocks (andesite); *2* = fluvioglacial gravel; *3* = ground moraine.

Region of Aconcagua-Mercedario, Lat. 32⁰ S.

North of Aconcagua (7030 m), the writer made extensive observations and ascents, but unfortunately his geological diary was lost.

No trace of pleistocene glaciation earlier than the last one (Würm) was found.

In the uninhabited upper valley of Rio de los Patos, the lowest distinct moraines were noted at 2400 m (below "Las Casitas").

In the narrow valley of Rio Colorado which collects its waters from half a dozen glaciers in the amphitheatre between Cerro Mercedario (6760 m) and Alma Negra (6100), the lowest distinct end moraine was found at 3500 m, only about 12 km E of the present Mercedario South glacier where the ice ends at the surface at 4150 m, and below the mantle of upper moraine at about 3900 m. The end of the ice under cover is usually well marked by the disappearance of the green upper moraine lakes.

Several moraines of retreat were encountered in Valle Hermoso (Rio del Volcan) 40 km NW of Aconcagua at 3000 m, and wonderful kars observed on the western slope of Cerro Cuerno (5500) m, 12–15 km NW of Aconcagua.

As a whole, in the arid region of the northern Argentine Andes, even the moraines of the last glaciation are comparatively small in extent.

On the Pacific side, Professor BRÜGGEN showed me at Puente Alto of Rio Maipó SE of Santiago, where this river enters into the longitudinal depression, intercalations of moraine in gravel beds, deposited at the end of the Würm glacier. According to this authority, the glacier of the last ice age on Rio Blanco NE of Santiago reached down to 1300 m above sea level, though no terminal moraines were found. The penultimate glaciation was much more extensive. In Puangue valley SW of Santiago, the ice, according to BRÜGGEN, reached even the level of 200 m, after having traversed the longitudinal depression (BRÜGGEN, 1934, p.165). This surprising statement needs further confirmation.

Actually, the coast region of Valparaiso has been raised 6,6 m since the colonial time and 0,6 m during the earth quake of 1906.

Paso San Francisco (27⁰ S.) Argentine-Chile

In this region, the summits of the Cordillera are made of volcanoes. The snow line in this desertic region is at about 6300 m, corresponding to the summit of the extinct volcano Incahuasi. No glacier was observed except a thick ice cap on the top and W-slope of the highest volcano of our globe, Ojos del Salado 6870 m, seen from Paso San Francisco. In this dry volcanic region, no pleistocene moraines were found on either side of the continental divide. BRÜGGEN states that 2 degrees further N in this plateau region called Puna de Atacama, even at 6700 m on the volcano Llullallaco, perpetual snow is absent.

Bolivia

Excellent studies have been made especially by C. TROLL (1929, 1937), TROLL and FINSTERWALDER (1935), and by AHLFELD (1945).

A uniform deposit of moraine covers the western slope of the Cordillera Real, about half way to the Titicaca Basin, where around 3900 m it passes into fluvioglacial conglomerate. It is regarded as belonging to the ultimate glaciation (Würm). With the aid of his most valuable photogrammetric surveys of the northern part of Cordillera Real 1 : 50000 and of La Paz Valley 1 : 15000, TROLL has demonstrated an older moraine below 100 m of fluvioglacial conglomerate (Riss?).

Glacial deposits were widespread over the high plateau (altiplano) of 4000–4200 metres. Thereafter, they were cut out by river erosion attacking from the atlantic side. A most outstanding example is the deeply cut valley of La Paz. A glacier tongue of the last glaciation (Würm or Bühl stage) flowed down into it as far as the terminal moraine at 3950 m level. In a new artificial outcrop below the skyscraper University building I have found typical moraine with scratched pebbles even at 3550 m, though not at 3400 as formerly stated by Hauthal. Thus, the end moraine at 3950 m (above the brewery Obrist) would belong to a stage of retreat of the last glaciation.

The highest mountain of Bolivia is the volcano Sajama, 6500 m, which carries a thick cap of ice. Its conic shape however did not permit the snow accumulation for a hanging glacier.

Peru

G. STEINMANN, in his classical book Geologie von Peru (1929) considers the depression of the snow line during the last pleistocene glaciation relative to the present one to be 600–700 metres. The regression observed during this century amounts to more than 100 metres and was still in progress (1947). Not only are the glacier tongues gradually retreating. In the case of Laguna Tulparajo (4300 m) in the Cordillera Blanca, the glacier tongue is breaking down and melting in situ. Within the last 3 years (1944–47), a lake has been formed in the place of the former tongue, which had a length of about 800 m and a measured depth of 55 m (description with photos in 7, 1948 d). Numerous catastrophs have occurred by such forming of glacier lakes, the pressure of which broke the moraine dam. The outbrake of Laguna Cohup of Dec. 13, 1941 caused the destruction of about one fourth of the city of Huaras (HEIM, ARN., 1948 d, photos 133 and 162); the last one of October 1950 destroyed part of the hydroelectric works of the Santa Valley.

The platform of Cerro de Pasco with its numerous lakes at elevations of 4000–4300 m has been covered with inland ice during the last glaciation and partly fed by glacier tongues which came down from the western Cordillera.

The lowest moraines were found on the western slope of the highest tropical mountain range, the Cordillera Blanca. In the side valley of Marcará, the Finiglacial (Würm) moraine just reached the longitudinal valley of Rio Santa at 2700 m. Farther north, at Caras, the huge erratic blocks of the former Parrón glacier seem to indicate that the glacier tongue reached down to about 2 km above Caras

(2450 m). Above the railway station of Mayucayán, on the right side of the young gorge of Rio Coronguillo, I observed at 2300 m a sharp moraine crest of a former glacier from Nevado Champara (5749 m), the northernmost glaciated peak of Cordillera Blanca. An accumulation of erratic granit blocks of the same origine was even found at 1900 m just above Mayucayán. This might be a rest of the penultimate glaciation.

Unquestionable *interglacial* and penultimate glacial deposits were found at the Baths of Chancos on Marcará Valley and in the Cohup side valley above the city of Huaras, though only locally exposed in the deepest erosional cuttings (HEIM, ARN., 1947 c and 1948 d). Fig. 3 shows the best outcrop.

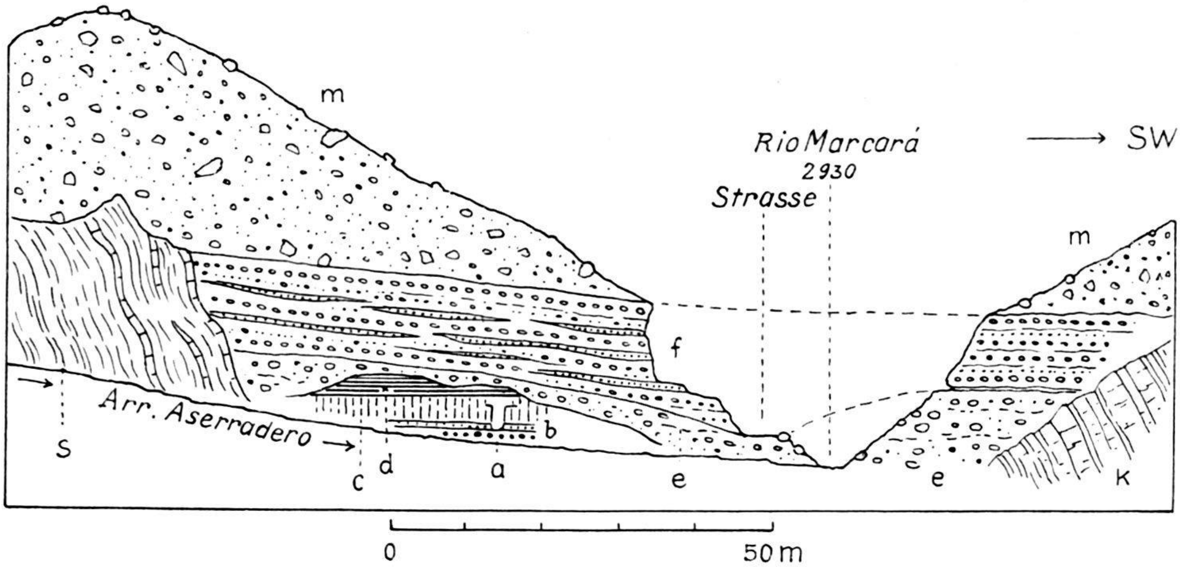

Fig. 3. *Interglacial deposits of Rio Marcará, Cordillera Blanca, Peru.*
k = dense Mesozoic limestone and shale; *s* = lower Cretaceous bituminous sandstone; *c* = 2,6 m greenish plastic clay; *d* = 0–2 m glacial varves; *e* = washed moraine with some more or less obliterated scratches; *f* = fluvioglacial gravel with lenticular layers of sand; m = lateral moraine of the last glaciation, 50–100 m high.

STEINMANN has already mentioned the conglomerate which underlies the moraines at Huaras (STEINMANN 1929, p. 278).

Regarding the last glaciation, two phases were distinguished which may correspond to the Würm and Bühl phases of the Alps. They have overwhelmed all the former glacial and interglacial deposits. Their moraines are spread over the western slope of Cordillera Blanca in great thickness. In the upper and wider (southern) part of Santa Valley, the moraines form rounded hills, while further down, walls 100–200 m high border the side valleys, demonstrating former long and narrow ice tongues.

Most wonderfully are developped in Peru the postglacial oscillations up to the present time. As shown by KINZL (1940, 1942), they correspond chronologically with those of the Alps, where the glaciers advanced in the years 1600, 1820 and 1850. Since then, with the exception of a small advance in 1920, all glaciers observed by me from Magallanes to northern Peru have been retreating or melting in situ, except the Moreno glacier of Lago Argentino. Even during the years 1943 to 1947, as already observed by BROGGI, OPPENHEIM and SPANN in Peru, the regression has continued. As the last oscillations coincide in both Hemispheres and across the Atlantic (KINZL), it is reasonable to assume also such a chronological coincidence for the larger Pleistocene glaciation periods.

Ecuador-Columbia

North of Peru are lacking my personal observations on the glaciation of the Andes.

The older moraines are widely covered by volcanic ashes and lavas. A very young uplift is illustrated by the recent erosion which reaches the inter-Andean region from the Pacific coast, and by elevated terraces.

In Columbia and farther north the relations of uplift and subsidence are more complicated, though my views regarding the relations of tectonics and former glaciation seem in general to be confirmed. It would be a fascinating task to study them in nature and with the necessary literature at hand, which at present is not in reach for me.

General Considerations

It is well known that the extension of the glaciations largely depends on climatic changes, and that the universal depressions of temperature were the main causes for the Pleistocene ice ages. Since the year 1850, the snow line of the Andes has retreated 150–200 metres. It is well known that during this space, almost all glaciers of our globe have been in retreat by general rise of the average temperature. The ocean water of the Northern Atlantic has increased 1—4^{0}. In addition to this influence come the local climatic changes in time and space, influenced by sea currents, winds and moisture. The latter are mainly responsible that the culmination of the climatic snow line of the Andes is far to the south of the equator, namely in the desert region of the Puna de Atacama, around 27° L. S., where I guessed it at 6300 m or even more.

A third and most important factor to these climatic causes is added by the *vertical tectonical movements*. Nowhere they seem to be so drastically illustrated as in the Andes. These movements may influence the glaciation in a positive or negative sense.

It was Steinmann, who for Peru already in 1929 has taken in consideration the influence of the vertical movements on the glaciation. In the Andes of Bolivia, Troll (1929, 1937) has studied the tectonical effects on the pleistocene glaciation, and Machatschek 1944 gives a review of this problem in the different continents.

A general uplift of the high Andes is assumed of 800–1000 m before the last interglacial period, and 500 m more in late glacial and recent time.

Not only the mountain ranges are an illustration of the uplift. More spectacular even is the formation of the Altiplano, which extends from northern Argentina (Puna) over Bolivia to Peru, where it gradually becomes dissected by recent erosion. Its average elevation in the central part is about 4000 m, but it reaches towards the Cordillera Real and in central Peru (Cerro de Pasco) 4300 m, whence its erosive relics towards north (Dep. de Ancash) seem to decline. Lake Titicaca, of 3800 m, in my opinion, is a young geosynclinal depression of the Altiplano. It seems to illustrate the uplift apart from sea level, where it may have been preformed in Mio-Pleistocene time. The little seahorse fish (Hippocampus) of the ocean seems to have gradually become adapted to the high elevation and the fresh water of the great lake in which it is living.

The uplift occurred slowly with periods of acceleration and standstills, as well as by shocks. The earthquake of Chillan in Chile of 1939 for example has produced a local uplift of 3 metres.

On the Pacific side of southern Peru, several superposed erosive terraces with slight inclination towards the ocean are an excellent illustration of *periodical uplift*. The highest of these terraces I found at 1300 and 1500 m.

Regarded as a whole, the Andes, being the longest uniform mountain range of our globe, are the most prominent illustration of vertical movements reflected in the topography. Schematically, they appear like a long geanticline, diverging to the north (Venezuela–Panama) and plunging to the south (Southern Patagonia). More accentuated is the cross section with the uplifted axes, the marine trough of 5000–6000 m depth on the west and the sinking jungle plain on the east flank.

Considering that the high Andes in early pleistocene time were 1000 metres lower than at present, then the climatic depression of the snow line was unsufficient to produce larger glaciers than the present ones. This seems to explain the absence of initio-glacial deposits in the central high Andes.

The contrary has been found in Patagonia, where enormous moraines of all main pleistocene glacial periods are distinguished, the initio-glacial ones which correspond apparently to Günz and Mindel in the Alps being of widest extension. At that time, the southern patagonian Andes were 1000 metres higher than at present. In addition to this former greater height and extension of the mountain range acted the general climatic changes with their depression of the snow line, which produced the full glacial development.

The above observations show that the distribution of *former glaciations can not be explained and studied geographically only, since they are the combined result of climatical and tectonical changes.*

APPENDIX

Observations on the Carboniferous Ice Age in Northern Argentina

In this region, most interesting phenomena of carboniferous glaciation were observed on both sides of the Precordillera of San Juan (lat. 31–32° S).

On its western border, at Barreal (Heim, Arn., 1945), the fossiliferous marine Mississippian is interbedded with tillites containing beautifully striated pebbles, showing that the glacier plunged into the sea.

On the opposite side (La Riconada), 180 km to the east, the tillites, partly shaped like modern moraines, are covered by sandstones and slates with a Mississippian flora (Heim, Arn., 148 b). Similar observations were already made by Dutoit 1929. The glacial scratches on the rock floor as well as the crystalline erratic blocks point towards the Pre-Cambrian crystalline ranges of the Andes about 300 km to the north. In that region (Villa Union, La Rioja, lat. 29°), a deep gorge in the gneissic basement is filled with tillite and covered with Mississippian sandstones, slates and coal beds with Rhacopteris (Estratos del Tupe of J. Frenguelli). Another valley of Mississippian age crosses the border range of the Precordillera of San Juan at Rinconada. These filling carboniferous sediments, together with the tillites, have been strongly folded in Pliocene time (Heim, Arn., 1946 c, 1948 b).

Zusammenfassung

Die vorliegende Schrift behandelt auf Grund eigener Beobachtungen die Beziehungen der quartären Vergletscherung Südamerikas zu den tektonischen Vertikalbewegungen. In keinem anderen Hochgebirge sind diese so auffallend wie in den Anden.

Im pazifischen Patagonien ist eine quartäre Senkung von etwa 1000 m anzunehmen. Die Folge davon zeigt sich in der Versenkung des durchtalten Gebirges zu den Fjorden und in der gewaltigen Ausdehnung der Moränen aller vier quartären Vergletscherungen auf der atlantischen Seite im Vergleich zu den spärlichen gegenwärtigen Gletscherresten. Sie kann durch die Annahme erklärt werden, dass im älteren Quartär die Anden bedeutend höher waren.

Im Gegensatz dazu suchen wir vergeblich nach deutlichen Resten einer Vergletscherung des älteren Quartärs (Günz-Mindel) in den Hochanden nördlich von Patagonien und der Chilenischen Schweiz. In Peru und Bolivia haben schon STEINMANN, TROLL und andere auf die quartären Hebungen von 1000–1500 m und deren Beziehungen zur Vergletscherung hingewiesen. Das Hochland der Puna (Altiplano) kann nicht anders erklärt werden als durch regionale junge Hebungen. Darum finden wir dort keine altquartären Moränenreste. Denn damals waren die zentralen Anden noch nicht hoch genug gehoben, um grosse Gletscher zu bilden.

Ähnlich wie in Patagonien sind auch gegen das Nordende der Anden hin wieder Senkungen anzunehmen, doch sind hier die Verhältnisse klimatisch, tektonisch und vulkanisch komplizierter und müssten erst mit Hilfe der Literatur und neuen Beobachtungen nach den hier gegebenen Gesichtspunkten untersucht werden.

References

AHLFELD, F. (1945): *Reseña geológica de la Cuenca de La Paz.* Mineria Boliv.

— (1946): *Geologia de Bolivia. Univ. nac.* La Plata.

BROGGI, J. A. (1943): *La desglaciación de los Andes del Perú.* Bol. Soc. geol. Peru.

BRÜGGEN, J. (1934): *Grundzüge der Geologie u. Lagerstättenkunde Chiles.* Heidelberg Akad. Wiss.

CALDENIUS, Carl C:zon (1932): *Las Glaciaciones cuaternarias en la Patagonia y Tierra del Fuego.* Geogr. Ann. Stockholm.

DUTOIT, A. L. (1929): *A geological Comparison of South America with South Africa.* Publ. Carnegie Inst. Wash. 381.

FERUGLIO, E. (1944): *Estudios geológicos y glaciolójicos en la región del Lago Argentino.* Bol. Acad. nac. Cienc.

HEIM, A. (1940): *Geological investigations in the Patagonian Cordillera (with map).* Ecl. geol. Helv. *33*, No. 1.

— (1945): *Observaciones tectónicas en Barreal, Precordillera de San Juan.* Rev. Museo La Plata, (N. S), Secc. geol., *2*, p. 267—286.

— (1946a): *La Expedición al Hielo Continental del Cerro San Valentin 1945—1946.* Mem. Club Andino Bariloche, Buenos Aires, p. 3—18.

— (1946b): *Informe sobre un Estudio Glaciológico en el Parque Nacional Los Glaciares.* Min. Obras Publ., Admin. gen. de Parques Nacionales y Turismo, Rep. Argentina, Buenos Aires.

— (1946c): *El Carbon de la Mina La Negra, Villa Union, La Rioja, y su posición tectónica.* Bol. Direcc. Minas y Geol., Buenos Aires.

— (1947a): *Auf die kontinentale Eisscheide in Peru.* Geogr. Helv. *2*, pp. 74—77.

— (1947b): *Region Pomacocha—Vilca, Prov. de Yauli y Cañete, Peru.* Bol. Inst. Geol. Peru *8*, Lima.

— (1947c): *Observaciones glaciológicas en la Cordillera Blanca.* Bol. Soc. Geol. Peru *20*, Lima.

— (1948a): *Das Peruanische Matterhorn.* Die Alpen, Heft 1, Bern.

— (1948b): *Observaciones tectónicas en La Rinconada, Precordillera de San Juan.* Bol. Dir. Minas y Geol., B. Aires, *64*.

HEIM, A. (1948 c): *Geologia de los Rios Apurimac y Urubamba.* Bol. Inst. geol. Peru *10,* Lima.
— (1948 d): *Wunderland Peru, Naturerlebnisse.* Verl. Hans Huber, 301 pp., map, 42 fig., 270 phot. and 12 col. pl. Glaciation especially in chapt. III.
KINZL, H. (1940): *Los Glaciares de la Cordillera Blanca.* Rev. Cienc. Lima *6.*
— (1942): *Gletscherkundliche Begleitworte zur Karte der Cordillera Blanca (Peru).* Zeitschr. Gletscherkunde *28,* Heft 1—2.
KLEBELSBERG, R. (1950): *Arnold Heim's Gletscherbeobachtungen in Peru.* Gletscherk. u. Glazialgeologie.
OPPENHEIM, V. & SPANN, H. J. (1946): *Investigaciones glaciológicas en el Peru 1944—45.* Bol. Inst. geol. Peru 5, Lima.
MACHATSCHEK, FR. (1944): *Diluviale Hebung und eiszeitliche Schneegrenzendepression, in: „Diluvial-Geol. u. Klima",* Geol. Rdsch. *34,* Heft 7—8, Stuttgart.
QUENSEL, P. D. (1911): *Geol.-petrographische Studien in der patagonischen Cordillera.* Bull. geol. Inst. Upsala, *11.*
STEINMANN, G. (1929): *Geologie von Peru.* Heidelberg.
TROLL, C. (1929): *Die Cordillera Real (Bolivia).* Ges. Erdkunde, Berlin.
— (1937): *Quartäre Tektonik und Quartärklima in den tropischen Anden.* Frankf. Geogr. Hefte, *11.*
TROLL, C. & FINSTERWALDER, R. (1935): *Die Karten der Cordillera Real und des Talkessels von La Paz (Bolivien) und die Diluvialgeschichte der Zentralen Anden.* Pterm. Geogr. Mitt. Heft 11—12.