THE GLACIERS OF MEXICO

Report of the Glaciology Section of the Mexican National Committee for the International Geophysical Year.

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Second Edition

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PREFACE TO THE SECOND EDITION

WHEN THE FIRST EDITION of this work appeared in mid 1959, it filled the purpose of presenting for the first time a catalogue of glaciers within the territory of the Mexican Republic. This had been entrusted to the author by the Mexican National Committee for the International Geophysical Year.

In this edition some minor changes have been made which do not alter the first work in its essence, except in the section corresponding to the Iztaccihuatl glaciers, which is entirely new. At the time of the IGY is was found impossible to carry out the study of the Iztaccihuatl because of the abnormal weather conditions encountered. The study of its glaciers was left for the end of the season, since from a mountain climber's point of view this volcano is the most difficult, and it was thought that by then our small group would be in good training.

The rainy season however arrived early that year and by the time we were ready to make our study, we found that the higher reaches were covered in new snow and the ice masses out of view; we postponed our work to the end of the year, but again found that the large snowfalls prevented us from carrying out our task as the data were still covered.

Later, in 1959 and 1960, the observations were made, and these correct those that in 1958 had been taken from a study of some aerophotographs made in 1945.

The new study was made with the help of the following: Raul Ocampo, Rafael Marquez, Leoncio Hernandez and Gonzalo Hernandez, together with Agustin Guerrero and Alfonso Muñoz, the last two and the author having been members of the oficial AGY team. In this edition, as in the previous one, the photographs appear without credits, except in the case of some commercial ones used. The authorship of the remainder is the Glaciology Section of the Geophysical Institute, of the National University of Mexico, formed by the above group.

THE MEXICAN NATIONAL Committee for the International Geophysical Year accepted the resolutions on Glaciology taken at the Brussels Conference of the Special Committee for the IGY of September 8th to 14th of 1955. These were announced as follows:

IX. 1 The CSAGI recommends that all national committees having glaciers which fall within their national purview be asked to submit complete lists of their glaciers by the end of the IGY.

IX. 2 The CSAGI resolves that at the conclusion of the IGY there be published as complete a list as possible of all known glaciers, recording as a minimum:

i) location and elevation,
ii) name,
iii) area (approximate),
iv) volume (estimated)
further, if possible:
v) photograph,
vi) measurements of activity,
vii) other observations of glaciological and meteorological value.

In accordance with this and taking into consideration the lack of experience in carrying out such studies, the limited equipment available and the shortage of funds, it was agreed to limit the activities of the glaciology group to a minimum, which would at least satisfy the first five points of those recommended in Brussels.

In charge of the field work was the author, who formed a group with Messrs. Oscar Gonzalez Rul, Agustin Guerrero and Ricardo Ferre. As the latter fell ill during initial stages, his place was taken by Mr. Alfonso Muñoz.

This group was provided with the necessary equipment for high mountain work, which allowed it to make prolonged sojourns at around 5,000 meters altitude.

Field work was carried out during April and May; it had been the intention to start in March, but the great snowfall of January, quite abnormal for these latitudes, covered the glaciers areas, and though in April it had not yet disappeared completely, work was begun. This delayed start, together with the early rain season, did not allow a study of Iztaccihuatl at the time, and this was left for the last weeks of the year. But abnormal weather condition again prevented it.

The field work, during which the data offered was obtained, was carried out during the months of March and April 1958, at the

time of the International Geophysical Year; in April, May and June of 1959, in a series of short expeditions, and in May and June of 1960.

For the work in hand, the following materials and data were available:

Cartography: A map made by the Empresa Hidroelectrica de los Volcanes, 1:20,000 scale, was genereously given by Mr. Bistrain, of the Popocatepetl and Iztaccihuatl areas. A provisional map of the Citlaltepetl, 1:50,000 scale, made by Estudios y Proyectos, A. C. and based on aerial photographs, was available, thanks to Mr. Felipe G. Mauriño (deceased).

Aerial Photographs: Those of Popocatepetl and Iztaccihuatl were obtained from the Cia. Mexicana de Aerofoto, S. A., and were copies of those made in 1945. Those of the Citlaltepetl were those of the Papaloapan Commission, taken in 1955, and copies of which were found in the Geography Institute of the University of Mexico. In both cases, the photographs were not of first importance, due to their age, but they were used more as a guide than as direct evidence.

Altimetry: Thommen pocket altimeters were used, graduated to 6,000 meters with 10 m. divisions. Four were used, all with tables of corrections, as established by the Mexican Meteorological Service. Temperature corrections were made based on e thermometer graduated to the nearest degree centrigrade. All readings were taken over the course of several days and at the same spots, in order to insure their correctness within the limits of the instruments.

In field work the following method was followed:

Iidentification of areas from aerial photographs, height reading and notation of compass directions (Brunton) which related them to each other. Thus the ice limits were noted and sketched.

It is our belief that in spite of the scarcity of technical aid, the errors will not be found too great.

II

THE GREAT ACTIVE and subrecent volcanoes of Mexico are distributed along two main fractures, those of Clarion and Chapala-Acambay, the latter a branch of San Andres fracture (Mooser, 1956). (SKETCH I).

Clarion extends from west of the Revillagigedo Islands, in the Pacific Ocean, to Orizaba Peak near the Gulf of Mexico in the east. It follows fairly closely the 19º N parallel and along it are found the Colima, Tancitaro and Popocatepetl volcanoes.

San Andres starts in California, follows a southern route along the California Gulf to the Maria Islands, and there seems to branch

out into various fractures. Among these, the northernmost one, the Chapala-Acambay, leaves the Maria Islands southeastwards and reaches land in the Tepic region, continues to Chapala lake, thence by Acambay, past the north of the Mexican basin and Tlaxcala, until it joins Clarion in the neighbourhood of Citlaltepetl or Orizaba Peak. Along it are to be found several large volcanoes, including Ceboruco, Malinche of Tlaxcala, and, probably, Cofre de Perote.

The other fractures which start at the Maria Islands go southwards and in wide arcs turn southeastwards. One enters the coast at the state of Michoacan and continues to Guerrero and Oaxaca states. Another forms the dividing line between the continent and the deep zone of the Pacific, and probably continues into Central America. It appears that volcanic activity was not great in the last two branches of the San Andres fracture.

In addition to the main fractures mentioned, and because of them, other smaller fractures, of a tensional character, were formed and between them made the so-called Volcanic or Neovolcanic Axis of Mexico. This is an area of some 900 kilometers long, and between 70 and 100 wide, stretching from Colima and Tepic in the west of San Martin Tuxtla in the east. It lies between parallels 18º and 19º north, except in the western end where it widens out to latitude 22º north.

This volcanic zone occupies a critical position in the epeirogenic structure of North America, separating, as it does, the high central plateau (Mesa Central of Mexico) from the rugged and deeply dissected terrain of Meso-America and hiding beneath its cover of late volcanic products the transition between these two diverse geologic provinces.

To some geologists, the Volcanic Axis fixes the southern limits of North America. That portion of Mexico laying to the south has the characteristics of Central America.

The area laying north of the Volcanic Axis, the Mesa Central, is a high plateau with a general altitude between 2,000 and 2,500 meters. Its rocks consist principally of limestones of Mesozoic age, covered in many places by volcanic flows and deposits of middle or late Tertiary age. The principal trends in this province are northwest. The area laying to the south of the Volcanic Axis, the Sierra Madre del Sur, in comparison, is extremely rugged, complex in geologic structure, and deeply eroded. Crystalline rocks and many intrusions characterize the province, while limestone of Mesozoic age and Tertiary volcanic rocks are restricted largely to remnants upon the higher eminences.

From east to west, there are to be found in this Volcanic Axis some active volcanoes, such as San Martin Tuxtla, Citlaltepetl or Orizaba Peak, Popocatepetl, Paricutin, Jorullo, Colima, Ceboruco and San Juan, and among the extinct volcanoes, Cofre de

Perote, Sierra Negra, Malinche de Tlaxcala, Iztaccihuatl, Tlaloc, Ajusco, Nevado de Toluca, Tancitaro and Nevado de Colima.

Of these, Citlaltepetl, Popocatepetl and Iztaccihuatl have areas covered by firn and ice, and Cofre de Perote, Malinche de Tlaxcala, Sierra Negra, Tlaloc, Ajusco, Nevado de Toluca and Nevado de Colima shows signs of glacial fenomena in fairly recent times (1). (SEE SKETCH I).

All are in the tropical zone, south of the tropical of Cancer, and the reason why there are still glaciers in Mexico is a consequence of the great altitude of the volcanoes, on which they are found, all over 5,000 meters. Those which had glaciers are mountain of over 3,800 meters.

III

CITLALTEPETL, from citlalli, star, and tepetl, mountain, Star Mountain, or Orizaba Peak, is the highest mountain in Mexico, with an altitude of 5,675 meters. This height has not been confirmed and there have been other figures given, but we have taken it as most probably correct, in view of our own observations.

Its geographic situation is 19° 02' latitude north and 97° 17' longitude west. It is about 200 kilometers east of Mexico City, on the edge of the Central Plateau. (SKETCHES I AND II).

From the 4,500 m line, Pico de Orizaba rose over an older and wide basement of which, its neighbour Sierra Negra (5,000 m) is the most conspicuous testimony. This basement was formed in Miocene and Pliocene time by volcanic complexes above which is the graceful cone of probably Pleistocene time. Principally formed by hornblende and augite andesite lavas with or without hypersthene, its upper part presents a young crater, oval-shaped with a major diameter trending NW-SE of 500 m and a minor diameter trending NE-SW of 400 m. It is still having some solfataras. (FIGS. 1, 2 AND 3.)

Because of its distance from Mexico City and the difficulties of approach it has not been studied much, even in its geological aspect. Waitz (1910 and 1915) and Mooser (1956) have brought forth the most accurate data, though there were others who have referred specifically to Orizaba Peak.

Waitz has the only glaciological mention (1910, page 75) from which we quote.

"While there are no real glaciers, there are to be found in cre-

(1) This part has been based on: Foshag, William F. and Jenaro Gonzalez R.: "Birth and Development of Paricutin Volcano";**Geological Survey Bulletin,** 965-D, Washington, D. C., 1956 and unpublished data from Federico Moose.

vasses on the north eastern, northen and northwestern side, superimposed layers of snow and hail".

We are obliged to differ, since we found there the greatest ice fields of the Republic of Mexico, so large and extensive that it could hardly have been formed in the few years between his visit and ours. Rather it would seem that Waitz's omission is due to his climb having been made along the old southern route, which crosses no glaciers, and that once he reached the crater edge, he was not a position to see the great ice fields that cover the northern side. As mountain climbers, we knew of the existence of the northern glacier, and it was only the IGY that gave us the opportunity to study it.

Shortly before he died, I had the chance of talking to Dr. Paul Waitz, in his double capacity of geologist and mountain climber. I showed him the photographs of the Pico de Orizaba glaciers, in greater numbers than those published here. He readily admitted that they were conclusive proof of the existence of the glaciers.

Our base camp for this glacier area was the Piedra Grande shelter, at 4,200 meters, at the foot of the northern face and on the edge of the majestic Jamapa barranca (FIG. 8). The Cueva del Muerto, on the southern slopes and at just under 4,000 meters, was also used.

The glacier zones of the Citlaltepetl cover particularly the northern side of the upper cone and the section between this and the Sarcofago or Blue Shoulder (5,030 m.) spreading out afterwards in various directions, and probably following the topography of the original lava flows. (SKETCH III, FIGS. 4, 5, 6, AND 7).

Our work started on April 24th, and we stayed on the mountain until May 2nd., where in spite of our training on Popocatepetl we suffered from high altitude fatigue. We were daily climbing to over 5,000 meters often under snow storms.

We found that the entire northern side is covered in ice, down to varying altitudes, the lowest being that of the two tongues into which the Jamapa glacier divides, and believed, as it was later confirmed, that we had before us the greatest glacier formation of Mexico. Due to the scarcity of local names for the glaciers, we decided to identify them in general according to their position on the compass.

Almost exactly north of the crater, is the Chichimeco tongue, wide and of a short length, which starts at the point known as the Half Orange (Media Naranja) — (point B in SKETCH IV.) Its continuity is noticeable on the eastern side, right from the edge of the crater at 5,650 meters, but on the western side it forms part of the huge mass covering the northern slope, and is not independent of it till the 4,780 line. (FIGS. 9, 10, 11 AND 12. SKETCHES III AND IV; I.)

There follows the one known as Jamapa, perhaps the most

pronounced of all. Starting at 5,000 meters in the col between the Sarcofago and the Peak itself, it runs northwestwards until it divides into two tongues, the eastern and the western, the first ending at 4,650 meters and the second at 4,640 meters. In both we found sub-glacial streams running at about 11 in the morning on sunny days, but frozen again by 6 in the evening. (FIGS. 11, 13, 14 AND 15. SKETCHES III AND IV; II.)

The western side of the ice field is the most spectacular. In it are to be found as many as five major tonges and several minor ones; some continue in the form of glaciers similar to the valley type and others become ice falls of 200 and 300 meters height without forming regenerated glaciers. (FIGS. 17, 18, 19, 20, 21, 22 AND 23. SKETCHES III AND IV.)

The western glaciers begin with the cliff ones; that of the Toro and the Barba (SKETCHES III AND IV; III AND IV). The lava has here formed a giant step, probably aided by glacier abrasion, to the edge of which the ice flows, to fall in great masses into the valley. Toro stops at 4,930 meters and Barba at 5,090 meters. There are no regenerated glaciers, possibly because the altitude at the botton of the fall is warm enough to melt the ice (FIG. 21).

There follows the western group (SKETCHES III AND IV; V, VI AND VII) which we named respectively Northwestern, Western and Southwestern. The first is a small tongue almost unrecogniceable in the mass of ice, which descends to 4,920 meters. The second, rather precipituous, goes down to 4,980 meters, and clearly separates from the 5,150 to 5,200 meter line. Finally, the Southwestern also reaches 4,980 meters, with a final stretch which is relatively smooth, from about 5,200 meters (FIGS. 22 AND 23).

The Eastern glacier (SKETCHES III AND IV; VIII) is somewhat isolated from the mass of ice, having contact with it only in the upper part, where it clings to the crater edge and even this contact is doubtful, for it is not fed by this area. It begins at 5,600 meters and reaches 5,070 meters. It is a steep glacier, with many crevasses and seracs, and difficult to climb, to the point that this has not been completely achieved yet. It is possible that Tobella and Samaniego were killed attempting it, for their bodies were found at the foot of this glacier. (FIGS. 24 AND 25.)

Actually all the glaciers, with the exception of the Eastern one, are born from the ice mass of the upper northern slope of Orizaba. Truly they are ice flows which because of topographical conditions leave the great ice mass, which we have called the Great Northern Glacier, to form short separate glaciers.

The area of the Great Northern Glacier is a little over nine square kilometers and the Eastern one 420,000 square meters, making a total for Citlaltepetl of 9.5 square kilometers, the largest in Mexico

and one of the most important in the tropical zone of the northern hemisphere.

There remains to define the exact ends of the cliff glaciers and observe the movement of the ice in the central zone, in order to find out where each tongue becomes independent, and even, to ascertain whether these tongues are not actually complete glaciers which start at the crater.

Through lack of equipment, ice thickness measurements were not made, but judging from the depth of the crevasses, and particularly the visible cuts in the Toro and Barba cliff glaciers, a major part of the Great Northern Glacier should be over 50 meters thick.

IV

POPOCATEPETL is the second mountain of Mexico (5,452 meters) and is on 19º 01' latitude north and 98º 37' longitude west, and about 70 kilometers southeast of Mexico City. This cone consists of many steeply dipping lava flows that are interbedded with thick unconsolidated layers of pyroclastics and its flanks coated with volcanic ashes. It seems its formation started with the Pleistocene. Its name means Smoking Mountain in the Nahuatl language, and in chronicles there is recorded another name it had, Xalliquehuac, which means "Mountain that throws out ash".

It is climbed from Tlamacas, a point at 3,882 meters reachable by road. (SKETCHES I AND II). Though it has been climbed and observed for centuries, mentions of its glaciers are few, and among them those of Aguilera and Ordoñez (1895) and of Farrington (1897). More recently, following the eruption of Popocatepetl in 1920-21, Waitz, Weitzberg and Camacho mention the existence of glaciers.

White (1954) published the first work on Mexican glaciers, and gave interesting data on the Popocatepetl firn field.

During the IGY, this was the first mountain studied (FIG. 26), and we camped on it from the 13th to 17th of April, first in the Teopixcalco shelter —4,950 meters—, and later on the lower Lip of the crater —5,197 meters— (FIG. 35) which we were forced to leave after a night of breathing the crater gases (FIG. 36) which proved to be harmful to our health.

While at the Teopixcalco shelter, we studied the Ventorrillo glacier (SKETCHES V AND VI; I) on its lower northern limit and its western side, where it is in contact with the remains of another glacier, the Northwestern, which goes from the Pico Mayor, or highest point of Popocatepetl, to the great cliffs of the western side, (FIGS. 27, 28, 29, 31 AND 38).

Our placing of the lower end of the Teopixcalco or Ventorrillo glacier was not very accurate since it was covered in recent snows, which in that sheltered area did not melt easely. However we believe, within an error of 20 meter, that it is at 4,690 meters. Its area is 435,000 m² approximately.

The Northwestern glacier (SKETCHES V AND VI; III) is hardly discernible, though from the abrasions on the rocks which bordered it on the west and southwest, it must have been larger in past times. In its upper part it rest on the Pico Mayor, and its lower part ends at the cliffs which are a characteristic of the western side of the volcano in its upper reaches. (FIGS. 27, 28 AND 31). Its separation from the Ventorrillo glacier is clearly defined from the 5,300 meters line. It covers approximately 95,000 sq. meters.

Once we had obtained the data of this area, we made a traverse of the Ventorrillo glacier, to set up camp at the lower lip of the rim of the crater (FIG. 35). During our encircling of the cone of Popocatepetl, we were able to see the remains of another glacier (SKETCHES V AND VI; II; FIGS. 27, 28 AND 37).

This glacier, or rather remains of a glacier, is the Northern. It is in contact in the west with the eastern side of the Ventorrillo glacier. The eastern limit is not clear, and must be oscillating since it rests on the volcanic ashes which cover this part of the cone. It ends abruptly, but without forming a cascade, therefore its thickness can-

not be great at the upper part of the Barranca Central. Later, and before we were put out of action by the fumes from the crater, we were able to establish the upper contact of this glacier, where we found visible parts of the rimaye, and we also established its contacts with that of Ventorrillo. It may cover about 190,000 m².

As we had no equipment with which to measure the depth of the ice, we have only been able to make a rough guess at it from the depth of the crevasses, the deepest of which in the Ventorrillo glacier and at an altitude of between 5,030 to 5,200 meters, are about 30 meters deep.

Generally it might be said that three glaciers on Popocatepetl are on the northern side, and share a common accumulation area, hard to be precise about, in its upper reaches, and later, between 5,300 and 5,250 meters, each acquires a certain independence. The very conical shape of the mountain would cause such a separation, just as in the past, separate tongues of ice flowed independently, as we were able to observe by the radial scratches on rocks.

At some future date it would be necessary to set up lines of poles to ascertain: a) a clear separation of the glaciers in their upper parts, now apparently common; b) the movement of each glacier, if any and c) the pertinent observations about the lower parts of each glacier.

Fortunately, there are enough rock bases on which to set up

points for theodolite observations, and even relate them to trigonometric points existing in the neighbourhood.

V

WITH AN ALTITUDE of 5,286 meters, Iztaccihuatl is the third highest mountain of Mexico. Geographically, its summit is at 19º 11' latitute north and 98º 39' longitude west, at some 60 kilometers southeast of Mexico City. It is a volcanic range the silhouette of which recalls the figure of a sleeping woman, whence its name, Iztac, white and cihuatl, woman, the white refering of course to the white of the snow and ice covering it.

Its geological history begins at upper Oligocene-Miocene with hornblende trachy-andesitic lava flows that formed the basal part. The erosion, actively working for a long time denies the possibility of identifying particular volcanic features. Lately, in middle-upper Pliocene, volcanic activity started again with porphyritic pyroxene andesite lava in quiet and wide flows that formed the actual Iztaccihuatl. In Pleistocene times the summit was formed by a small cone of red basaltic-andesitic scoriae and basalt (Mooser, 1956).

The formation of its present characteristic silhoutte, would seem to be due to volcanic and erosional factors, and glacial erosion played an important part.

Iztaccihuatl can be reached from the eastern and the western slopes, following roads and paths to high altitudes, as high as 4,000 meters by passable car roads. There are mountain club shelters as high as 5,000 meters.

On previous pages, we explained the difficulties we encountered on Iztaccihuatl: physical obstacles in 1958 and the need to make our study in two cycles, one in 1959 and another in 1960, in order to obtain the results which follow.

It is curious to note that Iztaccihuatl is the mountain with the most ancient references as to its glaciers. Father Jose Antonio de Alzate y Ramirez, member of the Mexican Illustration, sometime between 1781 and 1789 (Alzate 1831) mentions that in taking some barometric measurements he noticed "A great wall of ice, which because of its great with must have been formed since time immemorial". His findings, translated into the decimal system, give us a height above sea level of 4,633, which could have been correct.

In 1890, Ordoñez (1895) visited two glaciers on the western slopes, which appear to be the Ayolotepito and the Ayoloco, the latter being qualified by him as a hanging glacier.

Gilchrist in 1907 and Freudenberg in 1955 mention glaciers, the

latter being the first to refer to those on the eastern slopes, and it is not until 1956 that a more meticulous study is made of the Iztaccihuatl glaciers by White.

Recently, White (1962) has published the results of several seasons of study on this mountain, in a work, unique in its type, which while it only covers a study of the Glacial Geology of the west and northwest slopes, does make it easy to incorporate the data regarding the other slopes and even to understand similar fenomena in the other high volcanoes of central Mexico.

In our description of the glaciers we shall be referring to the mountain according to its more popular names, which follow those of the anotomy of the human being, and thus from north to south, we will find: the Head, the Neck, the Chest, the Belly, the Hips, the Knees, the Angles and the Feet.

The first glacier were shall mention is on the northern side of the Head, and is called the Head Glacier. It consists of an ice crust, which starting at 5,045 meters, descends to 4,900 where it ends abruptly at the top of the high cliffs known as the Cabellera (SKETCHES VII AND VIII; I). It covers an area of about 15,000 sq. meters, and is undoubtedly a cliff glacier, the ice fall having at one time started a new glacier at the base, where morraine marks are to be found. (FIGS. 39, 44 AND 48.)

To the East of the Neck and leaning on the slope that begins at the crest of the col between the Head and the Chest, is a rather inclined glacier known as that of the Neck; it descends from 4,990 meters to 4,760. Its area is of about 79,000 sq. meters (SKETCHES VII AND VIII: II. FIGS. 43, 44 AND 49). From its position it would seem to be part of a larger glacier which comes down from the Chest, and which because of its high situation remains to this day as a hanging glacier.

At the top of the mountain, at 5,286 meters, there begins a rather complex system of glaciers which we will call Chest Glacier group. The upper part, which is quite flat, has in recent years and perhaps due to unbalance, brought to light a semi-circular ridge, open to the East, which tends to confirm a theory that the Chest of the Iztaccihuatl is a small volcano of the Pleistocene age (Mooser, 1956; White, 1962). As it is above a great rock mass, also volcanic but of an older age, it is in a position to catch a certain amount of snow, which transforms itself into a great mass of ice, moving in several directions because of the topography. (FIGS. 40, 43 AND 45.)

In a clockwise direction and beginning at twelve, which in this case will coincide with the north, we find the upper part of the Ayolotepito glacier (SKETCHES VII AND VIII; III) which though it begins at the Chest, at the 5,250 mark, and with a decided northerly, descends abruptly in the first few hundred meters, turns West, to the left, to end at 4,760 meters. The topographical position, on the nort-

hern side of the Chest, protects it from the sun's rays, and from the strongest winds, those of the North East, and produces a great mass of ice, which does not come from the Chest (FIGS. 45 AND 50).

Nex to this, and also on the north, beginning at 5,250 meters, there is a small glacier hanging from an almost vertical rock wall, known as the Northern Glacier (SKETCHES VII AND VIII; IV). It ends suddenly at the edge of a cliff, at 5,050 meters, and at the base of this cliff, it regenerates into a small tongue running from 5,010 meters to 4,910 meters. (FIGS. 45 AND 51.)

Then we find the glacier that starts at the crater, 5,286 meters, and called the Crater Glacier. It is formed of two tongues: the first, the northeastern one, moves in that direction to 4,890 meters altitude, leaving two isolated masses lower down (the lowest point is 4,750) which because of their position seem to have broken off from this same tongue. (SKETCHES VII AND VIII; V). The other goes off clearly towards the East, but for a very short distance. It shows a chaotic form of seracs at 4,910 meters, which is continuously crumbling down a very steep slope. (FIGS. 45, 52 AND 53.)

On the WW side of the Chest, there is another cliff glacier (SKETCHES VII AND VIII; VI) under which there is no visible regeneration, possibly because the base is too low and also very steep. It begins at 5,286 meters and ends at 5,010. (FIGS. 45 AND 54.)

It must be stated that our division of the Chest system into the series of glaciers we have mentioned, is based on topographical signs. We would have to set up some stake lines in order to establish by their movement, the directions of movement of the Chest ice mass and so define the different glaciers.

Briefly, then, the Chest glacier system begins at 5,286 meters and at its lowest point reaches 4,760, and covers an area of 488,200 sq. meters.

In the region South east of the Chest there is small glacier, the Northeastern, which begins at 5,050 meters, descends to 4,830 and covers an area of 25,000 sq. meters (SKETCHES VII AND VIII; VII. FIG. 55). As it has an homogeneous surface, only firn was noticed, though there is ice in deeper zones.

The central part of the mountain, commonly known as the Belly is the beginning of another system of glaciers, but, and this differs from the Chest system, the dividing line between east and west is much more marked (FIG. 46).

One glacier goes eastward, the East Central (SKETCHES VII AND VIII; VIII. FIG. 56)which begins at 5,190 and goes down to 4,715 meters, with an area of 245, 000 sq. meters. On the western side of the Belly is the Ayoloco Glacier (SKETCHES VII AND VIII; IX. FIG. 57) which starting at 5,190 meters reaches as far as 4,725 and has an area of 274,000 sq. meters. This glacier, the best known on Iztaccihuatl, is cut by many crevasses and in its upper southern part, where

it rest on the Aguilera Rock, it has a series of dangerous seracs, but even so it this is the most used route for climbing the mountain.

Southeastwards runs the third glacier, the Southeastern (SKETCHES VII AND VIII; X), which starst at 5,130, descends to 4,950 and covers 77,500 sq. meters; though not large, it is very steep in its lower section (FIG. 58). Only a few meters away, to the south of the Belly System, there is another small system, that of the Kneess, formed by two glaciers, which like the two previously mentioned systems, are but zonal remains of the general Iztaccihuatl System, as it must have existed in former times (White, 1962.)

On the western side and separated from the Ayoloco by the Aguilera Rock, is the Glacier which we have called Atzintli (SKETCHES VII, VIII; XI) which starts at 5,080 and ends at 4,855, covering an area of some 57,500 sq. meters (FIG. 59).

This glacier was named after Dr. Atl, the Mexican painter, whose real name is Gerardo Murillo. His love of the high snow covered volcanoes of Mexico and his favorite style of panoramic landscape paintings, led the undersigned to name this glacier in his honour. Nahuatl language was used, and it was found that the simplest and most pleasant sounding word was to add to "atl" (water) the reverential suffix "zintli" with which a word is formed meaning Lord Water. Perhaps the purist will find fault with this coined word; let leniency prevail, for the intention is good.

To the southwest of this glacier, on the eastern side, is the small San Agustin glacier, named after the rock formation known as the San Agustin Tower (SKETCHES VII AND VIII; XI. FIG. 47). This small glacier, hardly noticeable in the snow field surrounding it, is the last remains of a larger glacier. From its present characteristics it can be called a circus glacier. It begins at 5,030 and descends to 4,970 m. It covers approximately 11,260 sq. meters and as far as is known is formed only of firn.

The large number of glaciers found on Iztaccihuatl indicate clearly the importance of the ice cap that must have covered this mountain during more propitious climatic conditions. Today's glaciers are nothing but remainders.

As to the thickness of the glaciers, we cannot give precise figures, for there are crevasses 50 meters deep and others no more than 20. The steepness of some parts, particularly in the eastern slopes, makes the lower parts be formed of firn, while this was not found on the western slopes, probably because they are more shut in and on lesser inclines.

A complete study of the Iztaccihuatl glaciers will be the most difficult of all because of the topography and because of the difficult access routes, now risky.

So far, we have seen that on Popocatepetl and on Citlaltepetl the glacier zones were in the northern slopes. On Iztaccihuatl, the

situation changes, the mountain running on a N-S axis, with glaciers on the east and west, with the latter ones being the larger.

VI

For their better study, the glaciers have been classified in different ways, by different authors. In our case we have followed the Ahlmann (1948) system.

From a morphological point of view, in which is taken into account the outer shape of the glacier, governed by the topography of its rock bend and the area and depth of the ice, Ahlmann sees three basic types, with some internal subdivisions:

"A. Glaciers extending in continuous sheets, the ice moving outward in all directions:
  (1) Continental glacier or inland ice, covering a very large area.
  (2) Glacier cap (or ice cap) covering a smaller area than a continental glacier.
  (3) Highland glacier, covering the highest or central portion of a mountain district.

"B Glaciers confined to a more or less marked path, directing its main movement. This group includes both independant glaciers and outlets of ice from glaciers of group A.
  (4) Valley glacier, of alpine type.
  (5) Transection glacier, the whole valley sistem being more or less filled by ice.
  (6) Cirque glacier, localized in separate niche on mountain side.
  (7) Wall-sided glacier, covering the side of a valley or some part of it.
  (8) Glacier tongues afloat.

"C Glacier ice spreading in large or small cake-like sheets over the level ground at the foot of glaciated regions. No glaciers of this type are independent.
  (9) Piedmont glacier, formed by fusion of the lower parts of two or more independent glaciers of (valley, transection, or wall-sided types in group B).
  (10) Foot glacier, the lower more extended portion of glacier of (valley, transection, or wall-sided types in group B).
  (11) Shelf-ice".

In the case of the Mexican glaciers, we could hardly include them in the previous classification; fortunately, this classification has been enlarged on by Willim O. Fields recently as follows;

1. Summit glacier occur on the summit of a mountain or strad-

dle a ridge and, therefore, flow in more than one direction. However, they are not extensive and do not qualify for ice caps in type A.

2. Hanging glaciers are those occupying a niche or depression of less extent than a valley on a slope and appearing to be hanging. The term is not the same as hanging valley or the glacier occupying a hanging valley. There is room for confusion here and possible another term should be applied. Many hanging glaciers are very small and may be designated as glacierettes. This type of glacier may be differentiated from Ahlmann's wall-sided glaciers in that they are isolated and usually of limited extent rather than an ice stream extending down the side of a valley.
3. Ice aprons or névé-sheathed slopes may occur on either concave or convex slope... These ice aprons cover the broad slopes of the mountains and in some cases extend into valley tongues... These névé fields, are intermediate between the snowfields and the ice tongues...
4. Cliff glaciers. This is a term applied... to describe a glacier terminating at the edge of a cliff.
5. Crater glaciers. These would appear to be a distinct, or dormant volcanic creaters which rise above the regional snow line. In some cases, the crater is completely filled with ice and flow tends to be outward in more than one direction... In other instances the flow is through a break in the crater wall.
6. Regenerated or reconstituted glaciers are glaciers which exist entirely below the firn limit and are fed primarily by avalanching from glaciers on the slopes above and not from avalanche slopes. Such glaciers commonly occupy a cirque or a valley and would exhibit some or the basic characteristics of these type. The principal criterion would be that the source of nourishment is from one or more other glaciers by means of avalanching.

According with given classifications, the Citlaltepetl and Popocatepetl glaciers are best included as Field's type 3. In part they are group A, type 2 of Ahlmann, but their dimensions would tend to exclude them. In the classification 3 of Field, they would belong but only as far the upper parts are concerned.

In the case of the Iztaccihuatl glaciers it would have been simple to include them all in Fields type 1, as they were no doubt originally. However, we now know that there is a crater glacier on the Chest, Fields type 5, and that possibly, due to the receding of the ice, some which were at first of type 1, have since become types 2, 4 and 6.

Having placed them morphologically, there now remains their

classification according to their geophysical characteristics, for which Ahlmann suggest there be taken into account ... "the consistency of the upper parts of the glaciers firn or compact ice and on the temperature of these". In the same work, Ahlmann gives his definitions (p. 55):

"1. Temperate glaciers consist of crystalline ice formed by fairly rapid recrystallization of the annual surplus of solid precipitation due to great quantities of fluid water. Throughout these glaciers the temperatures correspond to the melting-point of the ice, except in winter time, when the top layer is frozen to a depth of not more than a couple of meters...

2. Polar glaciers consist, at least in their higher and upper parts, of hard crystalline firn formed by slow recrystallization of the annual surplus of accumulated solid precipitation. The temperature of the glacier is negative even in summer down to certain depth. These polar glaciers can be subdivided into:

a) High polar glaciers, which consist, at least in their accumulation areas, of crystalline firn with temperatures below freezing-point to a considerable depth. Even in summer the temperature in the accumulation area is so low that as a rule there is no melting accompanied by formation of water.

b) Sub-polar glaciers, which in their accumulation areas consist of crystalline firn down to a depth of some 10 or 20 m. In the summer the temperature allows surface melting accompanied by the formation of fluid water."

It might seem paradoxical that the Mexican glaciers, in a tropical zone of the northern hemisphere, be classified as subpolar, but this should not really be surprising. The climate classification of Koeppen (1948) includes climates EF and EB, the first relating to polar caps (climate of eternal ice) and the second to the polar climate of high altitude, which is that found in the great heights of the Mexican Republic.

Up to the present, the only calculation that has been made of ice fields of Mexico was in Flint's work (1957) where a figure of 3 sq. km was given (p. 51; Tab. 4-A); the total of ice covered areas according to observations made during the IGY is near 11. 4 km², distributed as follows:

Citlaltepetl	9.500,000 m²
Popocatepetl	720,000 m²
Iztaccihuatl	1.164,550 m²
—	11.384,550 m²

The figure is approximate, with a plus or minus possible error, indicated in previous pages.