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NATIONAL RESEARCH COUNCIL OF CANADA

TRANSLATION TT - 64

THE SWISS FEDERAL INSTITUTE FOR SNOW AND

AVALANCHE RESEARCH ON WEISSFLUHJOCH NEAR

DAVOS AT 8700 FEET ABOVE SEA LEVEL

(Das Eidgenossische Institute fuer Schnee- und
Lawinenforschung auf Weissfluhjoch ob Davos, 2600 M.ü.M.)

translated by

D.A. Sinclair

This is the Fourth of the Series of Translations
Prepared for the Division of Building Research.

Ottawa

24 February 1943.

PREFACE

This is Report No. 1 of the Federal Institute for Snow and Avalanche Research on Weissfluhjoch near Davos, Switzerland. The translation is published with the approval of the Director of the Institute.

The National Research Council through its Divisions of Mechanical Engineering and Building Research has a close link with Eidgenossische Institut für Schnee- und Lawinenforschung. Mr. G.J. Klein of the former Division and the writer have both spent some time at the Institute. Dr. Marcel de Quervain who is now the Director of the Institute spent one year as a special member of the staff of the Division of Building Research during 1948 and 1949 and laid the foundation for the snow and ice research work to which the Division looks forward.

It is a pleasure to have this translation published since it describes very clearly the Institute with which the Council now has such a close link.

Robert F. Legget,
Director,
Division of Building Research.

REPORT ON THE SWISS FEDERAL INSTITUTE FOR SNOW AND AVALANCHE
RESEARCH ON WEISSFLUJJOCH OB DAVOS AT 2660 METRES
ABOVE SEA LEVEL

I THE PRACTICAL SIGNIFICANCE OF SWISS SNOW AND AVALANCHE RESEARCH

by M. Petitmermet, Inspector General of Forests.

Of all natural phenomena, avalanches are those which are most feared by people, for in this mountainous country they have a significance that must not be underestimated, having in the course of many years taken toll of numerous human lives and much property. It is not strange, therefore, that the authorities and the people themselves have been concerned about them at all times. However, until a few decades ago this concern was limited to avoiding damage. Actual prevention was either not considered at all, or was approached only with great hesitancy.

The earliest inhabitants of our mountain regions did in fact try to protect themselves against avalanches in a general way by establishing their settlements in places which presumably would not be reached by the avalanches. If they judged rightly in many instances, it is also true that fate often overtook them in the places where they imagined themselves secure. To avoid having to leave the afflicted localities, which were usually among the most fertile, they tried here and there to protect their houses by means of structural additions. Thus split corners or avalanche breakers were developed--in Praetigau they are called "Ebenhoech"*)--which are found in many localities, particularly, to mention some nearby examples, in St. Antonio and Frauenkirch, but also in Ticino and the Valais. The characteristic tendency, therefore - and it is easily understood - was for people to content themselves at first with breaking or deflecting the force of the avalanche after it had begun and was descending.

In the vicinity of Leukerbad deflecting walls which were built in the years 1721 and 1829/30 are still to be seen today, and are still in good condition. Guide walls for the protection of various objects have been built within the last decades, in the Valais for example, at the southern exit of the Loefschberg tunnel above Taesch in Saas-Grund.

*) Translator's Note: Wedge - form Projections

At an early date, however, it was recognized that it would be more to the point to prevent or to check the development of the avalanche, for only very strong, massive constructions are capable of withstanding a mass of snow descending in full violence. Although this view was not given general recognition until the second half of the last century, we know, nevertheless, that at an earlier date, mountain dwellers had already tried to stem the onslaught of the avalanche by constructing horizontal ditches, earth terraces, or embankments. Such structures can still be seen in the Valais, in Birch; for example, above Geschinen, and at other places in Goms. These were already in existence in 1786. Traces of old terraces have also been found in Ursuren and in the Lower Engadine.

The systematic obstruction of avalanches was not undertaken however until Coaz, then Cantonal Inspector of Forests for Grisons, was obliged to undertake the restoration of property which had suffered damage in the Lower Engadine during the late sixties. He built short, horizontal walls about one metre high, first in the township of Schleins, then later, in other nearby localities. As Federal Inspector General of Forests, he took a keen interest in this branch of his duties and himself drew the designs for defence projects in most of the Alpine Cantons. These designs called for wooden snow bridges, rows of props, and embankments, as well as walls. His example was followed by many forestry officials, so that, by the time he retired in 1914 a great many defences had been erected. These were almost all listed in the work, "Die Statistik der Lawinen in den Schweizer Alpen" - Avalanche Statistics of the Swiss Alps, 1910.

During the first world war, defence work ceased almost entirely, until a great deal of damage was sustained during the winters of 1917-18 and 1918-19, particularly in the Upper Valais. Some failures with the Coaz types of defence works led to the testing of new structural types. For a time, broad terraces of earth, stone or earth and stone mixed enjoyed great popularity. The experiences with these, however, were not so encouraging that the matter could be left there, and, consequently, the building of avalanche walls was again taken up. These, to be sure, were built much more strongly than before. Long walls, instead of short ones, were constructed in order to diminish the number of corners and wings, since these are particularly exposed to destruction. Through excavation of earth and stone behind the wall, a large space was created in which great quantities of snow might come to rest. A part of the excavated material was then used to reinforce the wall and to build it up along the top, thus enhancing its ability to withstand the violence of the avalanche and the impact of stone.

When a slope has been thoroughly obstructed by means of such works the danger is confined or at any rate greatly diminished. The disadvantage lies in the fact that these projects are very costly and their upkeep constitutes a burden which few communities can bear. Moreover, most of these great defence structures lie above the timber line. Consequently, they are not later replaced by growing woodland, but must constantly be kept in good repair. Moreover, experience shows that even when they are made from the best rock material and are built on sound engineering principles they still become dilapidated in as little as thirty or forty years. The low temperatures, the seepage of water, the great pressures and the blows to which they are subjected, are such that in a few decades the stone becomes eroded and the bond is loosened.

The obstruction of avalanches at the points where they develop above the timber line means a large financial burden, therefore, not only for the builders, but also for the Confederation and the Canton, which so far have always intervened whenever it was a question of reconstructing the defences.

The following figures give some idea of the extent and significance of the avalanche defence projects carried out from 1876 to 1942.

There were 587 projects in all, completed at a total cost of 16,531,900 francs. About sixty per cent of this expense was assumed by the Confederacy.

The Federal Inspectorate of Forests has long been searching for ways and means of reducing the costs of building and maintaining defences without jeopardizing the security which they offer.

The development of winter sports, and the consequent growth of accurate knowledge about winter conditions in the high mountain ranges, indicated the path to be followed. Until 20 years ago the planning of the projects was based solely on summer surveys of the areas of development, and on the very uncertain data supplied by local inhabitants. Thus it came about that some projects which at the beginning had been considered of subordinate importance gradually became more extensive, since it was revealed that the areas of avalanche development were much larger than had been supposed. Certain defences, like that of the Torrentalp ob Leukerbad or the Obergestelen were begun more than sixty years ago, and have not yet been completed.

Until the avalanche development areas were surveyed in winter, it was not possible to study the effect of the

defences from observations made on the spot. At the same time, it was realized that the conditions were by no means as simple as they had appeared when observed from the valley below. A more intensive investigation into the problem of avalanche development was therefore urgently indicated.

A conference was held under the chairmanship of the President of the Board of Education with representatives of the professors of the ETH^{*)}, the railroad engineers and the foresters in attendance, at which the desirability of an intensive study of avalanche development was recognized. Following this, a commission was set up in 1932 by the Federal Department of the Interior. This was first known as the "Avalanche Research Commission", but later, in line with the broadened scope of its duties, it was called the "Snow and Avalanche Research Commission". In the beginning, there were seven members; the number was later increased to fifteen. Its initial program comprised:

(a) The measurement of snow at rest; pertinent snowfall records, snow depth measurements with gauge rods, measurements of snow density with Sondes^{**)}, drills^{***)} and balances.

(b) Investigations of the dynamics of snow with special reference to the settling and movement processes in the snow-cover and the study of drifts.

(c) The provision of the necessary instruments and the establishment of the stations.

In order to carry out these tasks, several observation stations were first set up. These were situated on Col de Jaman (under Dr. Luetschg), on Saflisch ob Brig (Forestry Inspector Eugster), Andermatt (Cantonal Chief Forester Dr. Oechslin), in Elm (Cantonal Chief Forester Oertli) and on Weissfluhjoch ob Davos (Professor Staub of the ETH). Work was carried on conscientiously at these stations and abundant observation material was assembled.

In the course of time, every observation station was to be provided with a number of meteorological instruments such as rain gauges, barographs, thermographs, hydrographs, anemometers and sunshine recorders. In addition, there were to be snow gauge rods and snow tubes for the determination of specific gravity.

However, it was soon recognized that a satisfactory solution to the problems could not be attained in this manner.

^{*)}Translator's Note: Eidgenossische Technische Hochschule - Federal Technical University.

^{**)}Translator's Note: Swiss conical pointed penetrometer.

^{***)}Translator's Note: Cylindrical snow samplers.

Only an intensive study of the processes occurring in the interior of the snow-cover could provide information about the development of avalanches.

The first aim was therefore, to begin the systematic investigations into the mechanics of snow which had already been provided for in the program. This task was taken over by the hydraulics laboratory of the ETH in Zurich under the direction of Professor Meyer-Peter and has since been carried on unswervingly through the years.

The study of snow mechanics had scarcely begun, when it became necessary to examine the structure of the snow down to the snow crystal and its metamorphosis. To this end, the commission approached Professor Dr. Niggli, who readily offered his services. Since then, (the Winter of 1934-35), the representatives of the Mineralogical-Petrographical Institute and of the ETH Hydraulics Laboratory have worked together every winter, first in Davos, and then on Weissfluhjoch with the cooperation of Dr. Mbrikofer, Director of the Meteorological-Physics Institute of Davos.

It is expected that snow research will help, among other things, in the development of new types of avalanche defence works, whose cost of construction, and more particularly of maintenance, would be lower, but which would prove just as effective. Another important task is the study of drifts, which is of paramount importance for keeping the highways and railroads open, not to mention the ditches in areas where avalanche defences exist. Finally, snow research should provide the forester with ways and means of preventing the enormous damages which result from the creeping of the snow in the reforestation zones.

The original laboratory consisted of a frame hut just below the Weissfluhjoch station of the Parsenn Railway. Although the building was rather primitive, the workers of the commission were able to devote six years there to their task with great diligence and endurance. The management of the Parsenn Railway, which in any case always showed keen interest in our work and aided it in every way, also provided a space in the station building for an office. These circumstances lasted until 1941, when we were informed by the management that the frame hut would have to go. We were forced to find some way of making it possible to carry on the work. The commission suggested to the Department of the Interior that a new building should be erected.

After the necessary plans had been drawn up in the Winter of 1941-42 and the ground work had been completed, it was possible to begin construction of the new building in the Summer of 1942. The building was ready for occupancy in

December of the same year. During 1943 the interior fittings were completed and the low temperature equipment was installed.

Our country now has an institute which is unique. There is no doubt that in the course of time the results of the Institute for Snow and Avalanche Research will be of great importance to science and will contribute to the welfare and honour of our country.

II THE SCIENCE OF SNOW, AVALANCHES, AND GLACIERS IN SWITZERLAND
By Paul Niggli

In many cosmogonies based on mythology, the mutation of a primordial substance or state in earth, sea or sky is depicted as an elemental act, as one of the first deeds of the gods. The distinction survives in scientific terminology in the threefold division of a solid, fluid and gaseous state. And from the very beginning, water, which in the eternal cycle comes from the sky, mounts to the sky, seeps through the earth, flows to the sea, and which, by solidifying, becomes the prototype "crystal", suggested relationships concerning everything which is subject to mutation. Water is the substance which most forcibly and directly causes us to recognize the relativity of the terms solid, fluid and gaseous, and of the properties brittleness, fluidity and plasticity, and it is also the substance which, as an important requirement for the sustenance of life, and as a work-performing, energy-producing factor, is bound up with human destiny.

It is understandable that the crystallized forms, snow and ice, were not for a long time the objects of such intensive research as were fluid water and water vapour. In the thickly populated regions, snow and ice are phenomena which can be observed only fleetingly. It is altogether natural, that the need of coming to terms with them was first felt in mountainous countries. It must give us great satisfaction, however, that in a work on glaciology which appeared in 1942 (by Drygalski and F. Machatschek), which also deals with snow and avalanches, the historical section begins with the sentence: "The Alps are the home of the glacier formation. This is particularly true of Switzerland, where glaciers dominate the landscape at high altitudes perhaps more impressively than anywhere else, and where they consequently became the objects of scientific research at an earlier date." Indeed, the terms Gletscher (glacier), Firn (firn), Moraene (moraine), Guffer (moraine), Lawine (avalanche), Waechten (drifts), taken from the vernacular, were first elevated to the status of scientific expressions by Swiss scientists.

These facts at the same time imply an obligation that is enhanced by the opening up of the Alps to winter sport,

which is not without its dangers, and by our task of defending the Alpine passes, the heart of our native land, at all seasons and under all circumstances. Then there is the growing consciousness of the economic importance to our country of the whole matter of water conservation, whether in the form of solid or liquid precipitations, glaciers, avalanches, winter snow, or the gaining of reservoirs. Above all, however, the undying love of the mountains and the urge to penetrate the secrets of nature will continue to motivate those whose home is in the highlands.

In the Humanistic and late Humanistic era, the periods dominated by Bacon, Galileo, Kepler and Descartes, Switzerland took no appreciable part in establishing the principles of the sciences, either through scientific investigators or mathematicians. She surprised her contemporaries, however, with an abundance of valuable chronicles and cartographical presentations, and it was through these very documents that the principles of the science of glaciers, snow and avalanches, coming later, were introduced into the literature. Petermann Etterlin (1507), Aegidius Tschudi (1538), Johannes Stumpf (1548) and later Matthaeus Merian (1642) were the chief workers in this field. Descriptions of the snow-capped mountain ranges, in part still confused by ancient conceptions, were published by Sebastian Muenster (1543), Konrad Gessner (1541), and Josias Simmler (1574). For more than a century these descriptions remained the chief source material employed by the other naturalists of Europe. The information was collected encyclopaedically in 1606 in a didactic poem by Hans Rudolf Rebmann called "Poetisch Gastmahl und Gespraech zweier Berge" - Poetic Banquet and Conversation of Two Mountains. This poem also gave information about avalanches and glaciers and was still being cited by Scheuchzer on numerous occasions a hundred years later.

During the transitional period, before the first flowering of mathematical-scientific research in Switzerland, attention was given to snow and ice particularly by Johann Jakob Wagner (1680 and 1688) and Johann Heinrich Hottinger (1698 and 1709). During the period of enlightenment itself, Johann Jakob Scheuchzer (1672-1733) and Moritz Anton Cappeler (1685-1769) stand out as the real founders of the science of avalanches and glaciers. The former, for example, in his "Beschreibung der Naturgeschichte des Schweizerlandes" - Description of the Natural History of Switzerland - which appeared between 1706 and 1708, first classified avalanches as either dust or soil avalanches, mentioned causes of the loosening of the "Abschlipfen" - slides - described and recorded avalanche accidents, and reported in detail on the "Bewahr - und Rettungsmittel" - Methods of protection and rescue - then in use. In the third volume of the Natural History, there is a chapter dealing with

the "Gletschern, Schnee - und Eisbergen des Schweizerlandes" - The Glaciers and the Snow and Ice-clad mountains of Switzerland. Along with the general question, why our country is subject to glaciers, the growth and fission of glaciers is mentioned and is attributed to the pressure of water freezing in crevasses, and to the setting free of air. Objections, based on Hottinger's demonstration, are raised against the view, still represented by Simmler, that rock crystal is petrified ice. Parts of the processes of striation of glacier ice, and of the transition of firn into ice are already correctly indicated in principle. Cappeler proceeds differently. He constructs the first crystallography on the basis of Hottinger's crystallogia, and in it he carefully describes the different types of ice and snow crystal formation. In addition, it is already correctly determined that whether rock crystals, other stones, or ice are formed depends on whether the particles of the precipitate or of the water arrange themselves into uniform solid structures. Cappeler's contribution to Joh. Georg Altmann's "Versuch einer historischen und physischen Beschreibung der Helvetischen Eisbergen" - Attempt at an Historical and Physical Description of the Swiss Ice-clad Mountains - (1751) is the most valuable part of Altmann's work. The boulders lying on the glacier are correctly described as "debris which has fallen down from the mountains". The source region of the glacier is above, and "because new ice is always being formed from year to year, while the old glacier is always melting away externally on the valley side, the glacier must move continuously downward on the steep mountain slope, due to the pressure of the upper part on the lower, until it is finally melted by the heat of summer in the valley."

This was one of the first references to normal glacier movement, and at the same time, constituted a first rough theory about it. In the same work by Altmann there is a report of a trip from Geneva into the glacial fields of Savoy, which was undertaken by "scholars from Geneva together with some Englishmen who had been staying in Geneva for a time". The cooperation of tourists and scholars of foreign countries in opening up the Alpine region, which was later to be so fruitful for science, had begun. Not least among the influences leading to this development was a new didactic poem by Albrecht von Haller, "Die Alpen" - The Alps - (1729).

G.S. Gruner's great work appearing in 1760, "Die Eisgebirge des Schweizerlandes" - The Ice-clad Mountain Ranges of Switzerland - has a geographical description in Parts I and II, ending in a comparison with the northern glacial ranges of Scandinavia, Iceland, Greenland and Spitsbergen. Part III contains a general physical survey which does not offer much in the way of new material, but is valuable as one of the first complete presentations of its kind.

This early period of the study of snow and glaciers came to an end with the publication of H.B. de Saussure's work, (1779-1796), "Voyages dans les Alpes" - Journeys in the Alps - which laid the foundations for all Alpine research. This work is also justly considered to be a decided step forward for our field of study. However, the wealth of new observations and suggestions for experimental research should not make us overlook the fact that almost simultaneously particular aspects of the problems were being investigated just as conscientiously by other researchers. Above all, there are the two works of B. F. Kuhn contained in Volume 1 (1787) and Volume 3 (1788) of the "Magazin fuer die Naturkunde Helvetiens" (edited by A. Hoepfner) on the "Mechanismus der Gletscher" - Mechanics of Glaciers - (containing a correct explanation of the median moraines). An interesting piece of information is that a shepherd boy of Grindelwald had already tried to measure glacier movement in 1773. Contrary to de Saussure, Kuhn took the movement to be intermittent, but, like him, assumed that gravity was the driving force. At this time, Kuhn and de Saussure were violently opposed by foreign researchers who maintained that glacial movement was an absurdity. In the same yearbook an anonymous research worker gave a correct interpretation of the origin of the glacier tables. H. Besson and A. C. Bordier in 1770 and 1773 were the first to suggest the idea of flowing (in part, also, that of plasticity) for the movement of glaciers, for the mere sliding of a rigid mass over an inclined plane should result in accelerated motion.

The classical period of glacier and avalanche research falls within the nineteenth century. It bears quite plainly the stamp of the Society of Swiss Naturalists (Schweizerischen Naturforschenden Gesellschaft) founded in 1815. Later, the Swiss Alpine Club, the Federal Inspectorate of Forestry, the Central Meteorological Bureau and a great many visiting scholars from abroad took part. The first volume, which appeared in 1833, of the records of our present-day SNG^{*)}, (the scientific academy of genuinely Swiss stamp) contained the work of the Valaisan Cantonal engineer, J. Venetz, "Mémoire sur les variations de la température dans les Alpes de la Suisse" - Memorandum on the variations of temperature in the Swiss Alps, which had already been written from 1816 to 1821. What B.F. Kuhn, John Plafayer, and mountaineers Jean-Pierre Perraudin and Marie Deville had already suspected in part at least, now became a certainty through careful observation.

*) Translator's Note: Abbreviation for "Schweizerischen Naturforschenden Gesellschaft."

Moraines, erratic blocks and glacier polishings far away from the limits of the present-day glaciers, gave proof of an earlier, much more extensive firnification and glaciation. Thus, all at once, the phenomenon of mountain and continental glaciers of local character was revealed. New territory was opened up for the general study of geography and in a quick, triumphant sweep the ideas and observations stemming from the Alps permeated scientific thought as a whole, leading everywhere to new discoveries and setting new problems. What Great Britain was to stratigraphy, Auvergne to volcano research and Saxony to minerology, Switzerland now became to the study of glaciers and avalanches and to important sections of general geology. The concurrence of these scientifically new problems with the development of touring in the Alps led to deeds, especially, in the Berneralpine districts, which as feats of mountain climbing and scientific research, accomplished through perseverance with only primitive natural means must command our admiration.

Just a hundred years ago, a high point was reached with the works of J. Charpentier (e.g., "Essai sur les Glaciers" - Essay on Glaciers - 1841), Kanonikus Rendu of Savoy ("Theorie des Glaciers de la Savoy" - Theory of the Glaciers of Savoy - 1840), E. Desor in conjunction with L. Agassiz (e.g., "Excursions et séjour de M. Agassiz sur la mer de Glace du Lauteraar et du Finsteraar" - Excursions and Sojourn of M. Agassiz on the Mer de Glace of the Lauteraar and the Finsteraar-1841, and "Compte Rendu des Recherches de M. Agassiz pendant ses deux dernier séjours à l'Hôtel des Neuchâtelois sur le Glacier inférieur de l'Aar" - Account of the Researches of M. Agassiz, during his last two Sojourns at the Hotel des Neuchâtelois on the lower glacier of the Aar - 1843), L. Agassiz himself (e.g., "La Théorie des Glaciers et ses progrès les plus récents" - The Theory of Glaciers and its Most Recent Progress - 1842, "Etudes sur les Glaciers" - Studies of Glaciers, 1840 - 1842, and "Système Glaciaire" - Glacial System - 1847), F.J. Hugi (e.g., "Naturhistorische Alpenreisen" - Natural Historical Journeys in the Alps - 1830, "Die Gletscher und die erratischen Bloecke" - Glaciers and Erratic Blocks - 1843), the Scot, J.D. Forbes ("Travels through the Alps of Savoy", 1843), P. Merian ("Ueber Die Theorie der Gletscher" - On the Theory of Glaciers - 1841), and with the basic summarizing work of A. Mousson ("Die Gletscher der Jetztzeit" - The Glaciers of the Modern Era -1854). The German scientists H. and A. Schlaginweit worked successfully in the eastern Alps, and the expeditions of many scholars in other mountainous countries and in the polar regions extended the knowledge. Hugi (who was less fortunate in interpreting the erratic phenomena) discovered the polycrystalline core structure of glacier ice and thus established the connection between the structures of snow and firn. Agassiz and

his co-worker dealt with all the problems concerning glacial phenomena and carried out measurements of glacier movement from 1841 to 1846. Studies of the transformations from snow to firn and of the factors giving rise to movement were resumed, and it was of great significance that world-renowned physicists such as J. Tyndall (as early as 1857, but summaries in German were first issued in "In den Alpen" - In the Alps - 1875, and "Die Gletscher der Alpen" - The Glaciers of the Alps - 1898), J. Thomson, R. Emden (1890) and later H. Helmholtz (1896) took up the matter, although because of this, the theory of the exclusive predominance of regelation was propagated, which was afterwards a hindrance to progress. With the cooperation of SNG and the SAC^{*)} (founded in 1863) the Glacier College (Gletscherkollegium) was formed in 1868, which in 1893 became the Glacier Commission of the Swiss Society of Naturalists. As its first task, it undertook the exact measurement of the Rhone glacier. After the appearance in the eighties of basic works by E. Hagenbach-Bischoff and F.A. Forel dealing particularly with the questions of glacier nuclei and temperature conditions, the volume edited by P.L. Mercanton called "Vermessungen am Rhonegletscher" - Measurements on the Rhone Glacier - was published and must be regarded as the basic work dealing with this branch of the subject.

Meanwhile, however, Albert Heim (1885) had published the first handbook of glaciology, which was a fundamentally revised and greatly expanded edition of Albert Mousson's book; G. Finsterwalder had applied new methods of investigation; F. Muehlberg and Alphons Favre, followed by A. E. Penck, E. Brueckner, L. du Pasquier and many others, had enquired into the Alpine ice age, and (following books by F. Pfaff) H. Hess in his great work "Die Gletscher" - The Glaciers - 1904, had compared the investigations of the Alpine scientists with the outstanding works of northern scholars; and so on. Above all it must be mentioned that the standard work on the science of avalanches "Die Lawinen der Schweizeralpen" - The Avalanches of the Swiss Alps - had been completed in 1881 by J. Coaz, Federal Inspector General of Forests.

At the turn of the century, the International Commission on Glaciers was formed. Its recently broadened activities (with the affiliation of a Snow Commission), brought about with the splendid cooperation of American scientists were rudely interrupted by the war. The modern period, characterized by new information, the setting of new problems, and

^{*)}Translator's Note: Abbreviation for Schweizerischen Alpenklub - Swiss Alpine Club.

attention to practical requirements, began with this institution. While Albert Heim had already compared firnification and the formation of glacier ice with the process of marmoration, plastic behaviour with the folding of rock, and avalanche development with mountain slides, it was the crystal plasticity of ice discovered by Fr. Pfaff (1875), J.C. McConnell (1888-1891), and especially (1895 and after) O. Mügge, which led to new experimental principles. A partial elaboration of glacier mechanics was undertaken by B. Weinberg (1903), W. Philipp (1920) and others. Among the expeditions into polar ice fields which yielded new information, only those relating to the study of the inland ice masses of Greenland need be mentioned. Along with E.V. Drygalski, J. Koch, A. Wegener and K. Rasmussen, the Swiss A. de Quervain, P.L. Mercanton and E. Wegmann and their colleagues earned considerable honours for their work in this connection.

The development of meteorology and hydrology in the mountainous countries (brought about in Switzerland particularly by the Central Meteorological Bureau, the Physics-Meteorological High Mountain Observatory at Davos, the Federal Water Conservation Bureau, the Hydrology Institute and by O. Lüschg's fundamental work), as well as the systematic studies of the Federal Inspectorate of Forests on avalanche development and avalanche defence confirmed the knowledge that precipitation, evaporation, accumulation, transport and drainage of water had to be studied as a single whole in relation to all three states of aggregation. The building of roads and railways and the study and design of power stations brought new problems. Above all, however, the development of winter sports called for a thorough understanding of winter snow conditions in the mountains. It is the great merit of W. Paulcke that he recognized this at an early date (as early as 1896). In 1938, this mountain climber and scientist summarized the results of his observations over many years in the "Praktischen Schnee-und Lawinenkunde" - Practical Study of Snow and Avalanches-. Interest in such investigations continued to grow. General presentations with a wealth of illustration, such as M. Zdarsky's "Beitraege zur Lawinenkunde" - Contribution to the Study of Avalanches - (1929), G. Seligman's "Snow Structure and Ski Fields" (1936), W. Flaig's "Lawinen" - Avalanches - (1925), and our own "Lawinen, die Gefahr der Skifahrer" - Avalanches, the Skiers' Hazard - (1940) have achieved wide distribution. In 1931 a Swiss Snow and Avalanche Research Commission had already been founded under the presidency of Inspector General of Forests M. Petitmermet, which several years later began to make systematic investigations in Davos on Weissfluhjoch. These are to be carried on in future in the new institute.

Thus, high mountain research in Switzerland now has another laboratory in addition to the research station founded twelve years ago on the Jungfrauoch. Here it must attempt as a scientific contribution to the whole world to master the tasks imposed on it by nature. The strenuous efforts and kindly understanding of all are needed if we and our successors are to be found even to a small extent worthy of the great tradition of our forefathers.

The complexity of the phenomena calls for the continual cooperation of physicists, crystallographers, engineers, meteorologists, climatologists, hydrologists, foresters, glaciologists and geologists. A substance and a natural group of phenomena must be probed with all available scientific means. A synthesis directed towards a great process of nature takes the place of specialization, a beginning that by its very uniqueness may be destined to open the way to new insight into various fields. Where glacier ice originally constituted the starting point of the investigations, for us it is the snow fall, the winter snow covering and its metamorphosis which are to be the first objects of study. This in itself involves the behaviour of the firn, firnification and the formation of glacier ice, i.e., problems which can only be solved with the cooperation of the glacier commission and by full employment of the possibilities offered by the higher situation of the Jungfrauoch station.

The previous investigations reveal the immediate direction which the work must take. The snow profile is stratified and in constant transformation (metamorphosis). The causes of stratification of and change in the snow deposit must be studied in their dependence on snow falls and on topographical and climatological conditions. Although some of the lines of development are already recognizable it is certain that (corresponding to the variable weather conditions) the development of the snow-cover from year to year follows a somewhat different course, so that, as in the fields of meteorology and climatology, uninterrupted series of observations extending over decades are necessary. These are to be carried out, using every means, in the particularly favourable Parsenn region, but must be supplemented by results drawn from the many secondary observation stations in the mountain districts, and coordinated by the central station. The test methods already approved, which have been adopted by the military stations, too, and which facilitate comparisons, must be subjected to constant checking and improvement. The various types of snow covering, from the extremely porous, loose crystal of wild and powder snow, through wind-packed snow, surface hoar*) or depth hoar, to old snow, firn snow

*) Translator's Note: Harst = snow hardened by frost.

and finally glacier ice, are to be accurately characterized and examined for their mechanical properties of plasticity and rigidity (in relation to temperature and loading). Since it is a question of nuclear crystal aggregates of changing structure and texture, which to some extent are dependent on each other, it will be necessary to study the elementary processes in the nucleus of the snow and at the grain boundaries. The interaction of inner crystal plasticity with the phenomena caused by form and structure increases the complexity. Re-orientations and recrystallizations, either predominantly in the solid phase or combined with effects of the gaseous or fluid phases, are to be studied singly and in combination under varying conditions of stratification, temperature and load. Essential and indispensable as the field observations under the conditions of nature are, nevertheless, without experiments under simplified conditions, it will be impossible to separate the effects of the different factors. Accurately reproducible, artificial snow types must be manufactured, subjected to metamorphosis, and examined for their mechanical properties. Knowledge of the behaviour of synthetically produced ice crystals will in many cases be essential to the understanding of the complicated natural processes. Only after a refrigeration machine assuring constant temperatures has been installed will our laboratories be adequate for this purpose.

Comprehensive investigations of this kind are so closely related to two technically important fields of investigation that it may confidently be expected that the results obtained in the snow laboratory will be of importance to them also. One of these fields is metallurgy. The metal substances, too, are crystal aggregates which may be deformed and recrystallized, and whose treatment by heat and cold requires an intensive study of their metamorphoses, plasticity and fluidity. In snow and ice a transparent substance of low melting point is now available in which all these phenomena may be followed microscopically at the handling temperature, which is indeed an advantage. On the other hand, as shown particularly by the work of our colleague, R. Haefeli, soil mechanics will not only be able to contribute to snow research by its methods and definitions, but the work done on the particularly plastic and changeable loose crystal snow will be of great significance for an understanding of the processes in clays, the creeping and sliding of the ageing soil (Altern) for example, and for the calculation of the earth pressure and tension ratios.

With a definite purpose in view, material must gradually be collected in the fields of investigation, and in the labor-

atory, the treatment of which will clarify the complex relationships of water conservation in the high mountains (precipitations in various forms, evaporation, melting, drainage). Above all, however, the study of the sliding and creeping processes of the snow loads on slopes, of the natural and artificial formation of avalanches and of snow drifts in relation to the formation and re-formation of the snow covering and its internal sliding surfaces, will contribute ever more abundantly to the prediction of avalanches and to the construction of avalanche defences, which are so costly. The provision of great security for man and his works, and the prevention of accidents by provision of advice and protective measures are certainly goals worth striving for.

Necessary as it is for the responsible scientist to insist that at first he should be allowed to do his research, and that so called "practical work" should not be demanded of him on the basis of unclarified and faulty information, he will nevertheless always be ready to make himself available for the requirements of the hour. Our station is to be a scientific research station in which problems are to be examined at long range. The fact that the workers do not forget what the outside world expects of them is shown by the continual forecasts of avalanches in the wintertime, which have prevented many an accident, and by the passage in the 1942 regulations of the Swiss Army on "Weather and Avalanches" which reads:

"Since our army began to make use of the results of the Swiss Snow and Avalanche Research and has instituted an avalanche corps, no great disaster has occurred, in spite of the manning of sections of the mountains by troops, often at great risk of avalanches."

It was of course obvious that our colleagues would immediately place themselves at the disposal of the army for the purpose of setting up an avalanche corps. We owe it to them that just four years after the inauguration of the new studies results were available which could be evaluated practically and which later caused even belligerent states to pay particular attention to the first publications of the Snow and Avalanche Commission.

III THE AVALANCHE CORPS OF THE ARMY
by Edwin Bucher

There are numerous reports in the literature which state that on the Tirolian mountain front during the last world war, more human lives were lost through avalanches than from all the artillery, automatic weapons, rifles and hand grenades together. W. Paulcke, who was well acquainted with the winter warfare of that time estimates the number of avalanche casualties from 1914 to 1918 at 60,000. Along with the direct threat to the ski trooper, the avalanche problem acquires great significance with reference to our lines of advance and supply. It was fortunate therefore that the systematic investigations of snow on Weissfluhjoch had reached a tentative conclusion at the beginning of the present great war. In full realization of these difficulties, which would beset both the enemy and our own troops during a winter campaign, our high command at once familiarized itself with the practical results of the snow research on the outbreak of hostilities. The avalanche division, organized in the Canton of Grisons with the aid of the personnel of the Weissfluhjoch station was introduced into all units of the army. Soon the armed frontier posts of our mountain front were strengthened by addition of the avalanche sentries, whose task it was to inform their comrades, by means of continual observations, measurements and reports, on snow and avalanche conditions. The statistical material obtained in this way is compiled each year into comprehensive reports which provide a clear picture of the varied conditions in the mountain zones and which represent important preparatory work for subsequent scientific and practical investigations.

In numerous, annually repeated courses officers and men of the entire army have had a glimpse of the modern war against avalanches. For these courses the personnel of the Snow and Avalanche Research Commission acted as directors and lecturers. The leading position which Switzerland has gained in the scientific treatment of snow during the last ten years could thus be made available for the military preparedness of our country.

IV ILLUSTRATED DESCRIPTION OF THE INSTITUTE
by Edwin Bucher.

Plain, slate-gray, blended to the natural colours of the mountains, the Federal Institute for Snow and Avalanche Research stands before us. It seems to grow right out of the rocks, although, it is of the most modern architecture, so that together with the station building of the Parsenn Railway it forms a harmonious whole. It is no show place!

Its stone and wood facade is right at home in the rugged mountainous country, yet it is not long since the first workmen set foot on the building site to shape and bond the rock drawn from the dark hillside debris and to build it up into the completed structure. The difficulties with which the contractors had to contend at this altitude, the damp, cold, rainy weather of the first days of excavation, the winds blowing in among the rude turmoil of scaffolding poles and planks, all are forgotten. Masons, carpenters, joiners and plumbers, all have combined to provide the young offspring of advanced national research with a sturdy shelter and at the same time a pleasant working environment.

From the terminal station of the Parsenn Railway, we reach the Institute through a passageway which provides protection against all weather conditions and which also serves as a storage space. Here two sections of the building, divided by a vertical partition, fulfill the various requirements. On the north side, which is also the mountain side are two artificially cooled laboratories, built on two floors one above the other. In these the crystallographical and mechanical properties of snow are investigated. The organization of space in this cold, almost windowless section is determined by apparatus and installations of all kinds. All the refrigeration machinery has been installed in the corridor below the stairs joining the two laboratories, where it occupies the smallest space compatible with the requirements of supervision.

On the south side of the well-insulated partition, which sometimes has to bridge temperature differences as high as 35°, is the office and dwelling space which is comfortably heated by the sun's rays and a central heating plant. The upper storey is set aside for the scientists, each with his private office and commanding the services of a common secretarial department. The simple, altogether functional arrangement of the area makes it possible to manage with a minimum of space while still not giving any impression of cramping. The office furnishings, executed in unplanned fir to match the wall panelling were for the most part built in, so that all available space might be used. Broad box windows, equipped with ingenious ventilation slots, provide a magnificent panoramic view of the surrounding mountain scenery from the nearby Schiahorn as far as the Kesch and Bernina districts.

Proceeding down the stairway, which is inlaid with red tile, the ground floor is reached, containing a large draughting room, a four-bed dormitory, the dining room and the institute kitchen. Here, too, a striking degree of comfort has been attained in all the rooms with modest, but dependable

and well-considered means. The basement contains a workshop, designed to fit the needs of the Institute, and also the dark-room and a filing room for special investigations.

The first workmen arrived at the building site on June 22, 1942, and the Institute was ready for occupancy by the end of December of the same year. In view of the difficulties of transportation and the altitude at which the building operations took place, it must be mentioned that the contracting firm, the Davos-Parsenn Railway and the other companies participating did everything in their power to complete the building within the shortest possible time. The Sulzer radiant heating plant, the first of its kind to be installed at this altitude, and the refrigeration plant, also constructed by Sulzer Bros., Zurich, in cooperation with Therma, of Schwanden, may be of technical interest.

The great difficulties attending the transportation of fuels, whether coal, wood or fuel oil, to an altitude of 2700 m. above sea level, from the very beginning favoured the choice of an electrically operated heating plant. The presence of an electro-thermal storage tank, with a capacity of 4600 litres, in the basement enables the Institute to take full advantage of the low night power rates. The four-stage heating element of 80 kw. connected load assures the heating of the water to a maximum temperature of 100° between 10:00 p.m. and 6:00 a.m. In view of the gain in space and several other simplifications of a structural nature which would result from the elimination of radiators and visible conducting pipes, the radiant heating system proposed by the firm of Sulzer Bros. was selected.

The operation is simple, due to the fact that the temperature of the circulated water is always adjusted to the mean outside temperature at any given time. This is accomplished by setting a thermostat which is coupled to a mixing valve. To maintain a check on both the water temperature and the thermostat a mercury thermometer was installed. If due to a breakdown or to improper operation of the equipment the temperature of the water should exceed 55° - which would result in excessive thermal stress in the concrete - the circulation of the water is automatically discontinued by a mechanically operated safety device. The actual heating bodies, the coils, which are tested at 35 atmospheres, were cemented into the ceilings of the separate rooms, which were reinforced on the basis of calculations by the Rathgeb Engineering Bureau. The ascending and connecting pipes were likewise walled in, but not the pipes connecting the storage tank with the expansion tank, which owing to the flat-roof construction had to be set off by itself outside the concrete shell.

The experience with this radiant heating since January, 1943, may be termed satisfactory. The cost of heating for the year 1943 came to an amperage rate of 2.5 or 4.5 Rp^{*)}, depending on the season. By the most simple means of operation, it was always possible to heat all the rooms satisfactorily within a relatively short time, even when the outside temperature was very low or when the weather was stormy.

Artificial cooling of the laboratories was necessary for several reasons. In the first place, working with snow in the laboratory required a room temperature at least far enough below freezing point to prevent melting of the preparations by the body heat of the investigator, whether radiated or conducted through instruments in contact with them. Experience has shown that these temperatures may not exceed -5°C . Without artificial cooling, this condition is attained at low outside temperatures only in the upper laboratory, which has direct exits into the open air; in the lower rooms, which are bedded in the mountain, the heat of the ground and the effects of radiation are too prevalent. Moreover, the investigations of the last few years have shown that temperature plays a decisive part in the behaviour of the snow-cover. For example, the slow metamorphosis of the new dendritic snow crystal into the old snow grain, which also affects the mechanical properties of snow, is remarkably sensitive to temperature changes, particularly in the vicinity of the freezing point. Only the possibility of keeping constant or of changing the temperatures of the laboratories at will within broad limits, regardless of the meteorological conditions, will enable a further development of the results so far obtained from snow research to be carried out. Thus, for example, parallel tests with identical sample material can be carried on in rooms cooled to different temperatures, a procedure which could scarcely be followed in nature. Finally, artificial cooling further makes it possible for the laboratory tests to be extended beyond the season of cold weather, and, indeed, to a limited extent enables them to be continued right through to the following winter.

These considerations led to the decision to have a low temperature plant installed in the already completed Institute during the summer of 1943. With this in mind, certain constructional arrangements had already been made during the planning of the building, so that now the work was mainly confined to increasing the thermal insulation of the laboratories and to

*) Translator's Note: 1 Rp (Rappen) = 1/100 fr. (Swiss).

installing the refrigeration plant.

The special performance demands which must be made on the plant can likewise be deduced from the requirements indicated above. As long as snow is available on Weissfluhjoch, that is to say from the beginning of October at the earliest until the middle of July at the latest, the upper laboratory is cooled to a temperature of -5° for the conducting of experiments in snow mechanics. During the same period a laboratory is required for crystallographical and physical researches with a temperature of -10° , as well as two cold chambers with temperatures of -20° and -40° , respectively, which are adjustable for all intermediate degrees. Thus the entire range of temperatures to be met under natural conditions in our region is covered. During the summer season, the mechanical tests and the researches involving extremely low temperatures are discontinued. In the crystallographical laboratory, and in the two cold chambers, a temperature of only -10° is then required. An awkward circumstance for the technical execution of the plant was the fact that no water was available for cooling, and that the use of electrical power during the running season of the Parsenn Railway had to be confined mainly to the night hours. The dining room circuit of the railway, to which all the electrical plants of the Institute are wired, was not originally designed to take a supplementary load. The two firms commissioned to build the low temperature plant provided the following solution to the problem which has proved satisfactory.

A "Frigoroto-Sulzer" ammonia circulation refrigeration machine of about 8200 Kcal/hr cooling capacity cools a brine cold storage tank during the night hours to a temperature of -24° . On the compression side of the ammonia compressor the heat drawn from the brine solution is passed directly into the open air through a finned tube condenser. The liquefaction temperature of the ammonia can be set high enough to assure cooling at an outside temperature of $+10^{\circ}$. A system of pumps forces the cold calcium chloride brine in amounts determined by the thermostats into the laboratories and causes it to circulate through the cooling coils installed in the ceilings. For these small amounts of work, as well as for various ventilators, oil pumps, etc., electrical power is available throughout the day.

When the outside temperature is below -5° , it is possible to cool the upper laboratory with outside air, thus reducing the cost of operation. If during this manner of operation, the outside temperature should rise above the setting of the thermostats, the refrigeration machinery switches on automatically.

Two additional compressors take care of the low temperature cooling of the two special chambers. These are a "Therma-Kuehlautomat" with a two cylinder high and low pressure compressor for chamber II (-40°), and a "Therma-Kuehlautomat" with a two cylinder half-compressor for chamber I (-20°). The Freon evaporators are in the chambers themselves; thus there is no storage of cold. The advantageous combining of the Sulzer storage equipment with the Therma equipment consists simply in having the condenser which serves both Therma machines submerged in the brine tank, so that for the extra low cooling only the temperature difference between the brine and the air temperature in the chambers has to be generated.

All the switch mechanisms needed to regulate the temperature in the laboratories are automatically controlled, so that temperatures can be held within approximately 2° . Other installations which have still to be mentioned are a system for the provision of fresh air and an arrangement for defrosting the cooling systems.

V FUTURE PROJECTS

ALPINE ROADS AND MOUNTAIN RAILROADS:

Clarification of the principles for constructing snow removers and plows. Protection against drifts and avalanches. Snow pressures on artificial structures.

TRAFFIC ORGANIZATION:

Development of winter traffic by investigation of snow and avalanche conditions. Obtaining favourable conditions for all transportation facilities in winter.

BOTANY:

Effect of snow covering on the germinating power of seeds. Heat conservation and plant growth. Avalanche development and plant sociology. Damage to vegetation caused by creeping of snow.

EARTHWORK RESEARCH:

Snow is a porous aggregate similar to the raw material of soil. Valuable information on soil mechanics may be gained by comparison with snow, since in part analogous methods of investigation may be applied.

AVIATION:

Making landing strips on snow and firn. Ice formation on load surfaces of aircraft.

FORESTRY:

Effect of the creeping of the snow-cover on avalanche defence works and reforestation plots. Damage to forests inflicted by avalanches. Principles of avalanche defence.

GLACIER RESEARCH:

Glacier formation, movement and melting processes as the limiting state of snow-cover development.

ADVANCED RESEARCH:

Since this is the first, and until recently the only institute for snow research in the world, it has a duty to perform of enhancing our national reputation as a centre of international research.

HYDROLOGY:

Water content of the snow-cover, duration of the melting process, water retention properties of the snow-cover.

CIVIL ENGINEERING:

Development of standards for construction on mountains, security measures for avalanche defence works, deflecting walls, force breaking devices, artificial release of avalanches, etc.

ELECTRICAL POWER PLANTS:

Influence of the snow-cover on water supply, protective measures for power plants situated at high altitudes.

VEHICLES:

Clarification of the constructional principles for snow removers.

METAL INDUSTRY:

Investigation of the metamorphosis of the crystal form and of recrystallization in ice (analogous to metal) and snow (analogous to powdered metal). Favourable research conditions (polarized light and transparent material).

METEOROLOGY:

Relation between weather conditions, snowfall and avalanche danger. Study of the effect of the snow-cover on climate. Observation of the hydrometeors and their relation to the danger of ice formation on aircraft.

MILITARY SCIENCE:

Development of principles for a winter mountain war. Snow and avalanche conditions on advance and supply routes. Experiences with snow and ice. Avalanche development. Effectiveness of arms in snow. Protection of permanent installations (garrisons, overhead cable railways).

SKIERS:

Assessment of snow and avalanche conditions, waxing problems.

ROAD BUILDING:

Frost problems in road pavement, the snow-cover of Alpine roads and its removal, avalanche defences, snow pressures on fences, drift problems.

ACCIDENT SECURITY MEASURES:

Protection against winter sport and traffic accidents by means of lectures, publications and bulletins on the avalanche and snow conditions. Prevention of avalanche catastrophes.

WINTER HEALTH RESORTS:

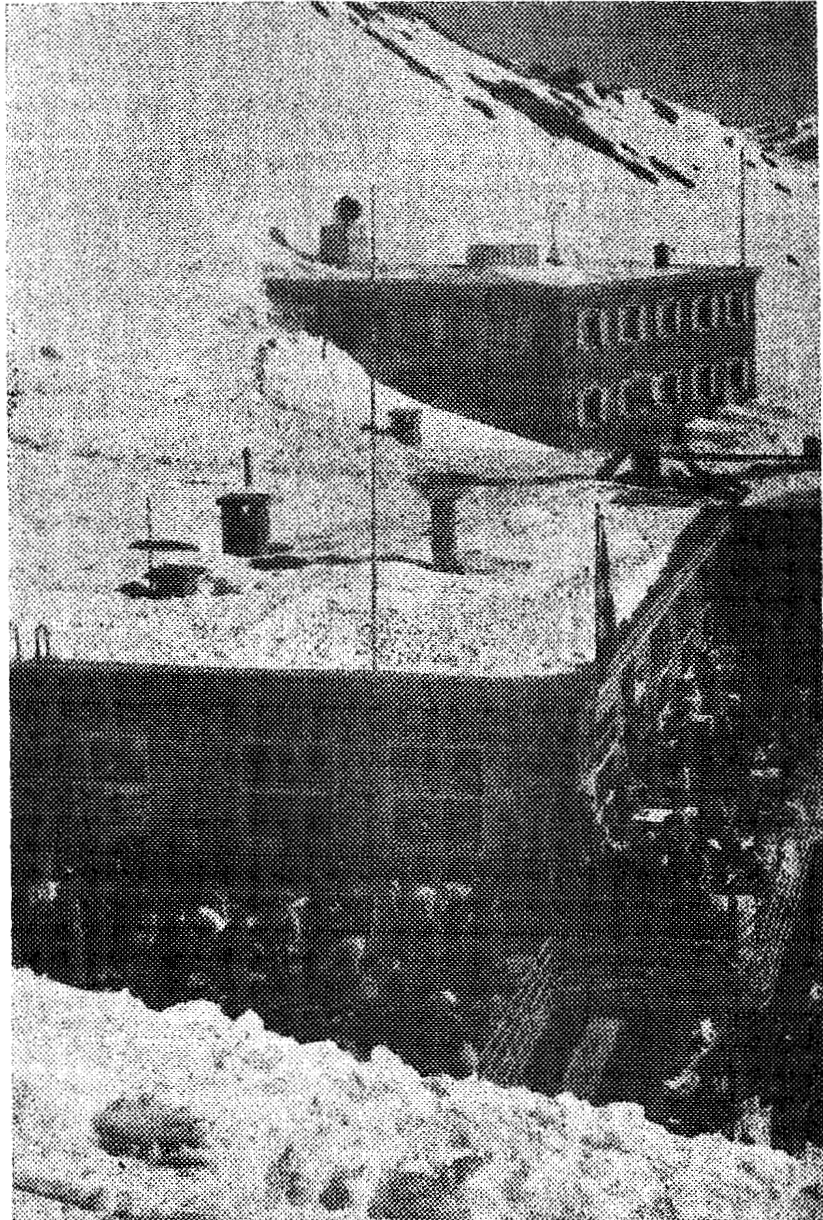
Prevention of avalanche accidents, information and rescue services, traffic security, spread of winter sports

VI LIST OF PUBLICATIONS

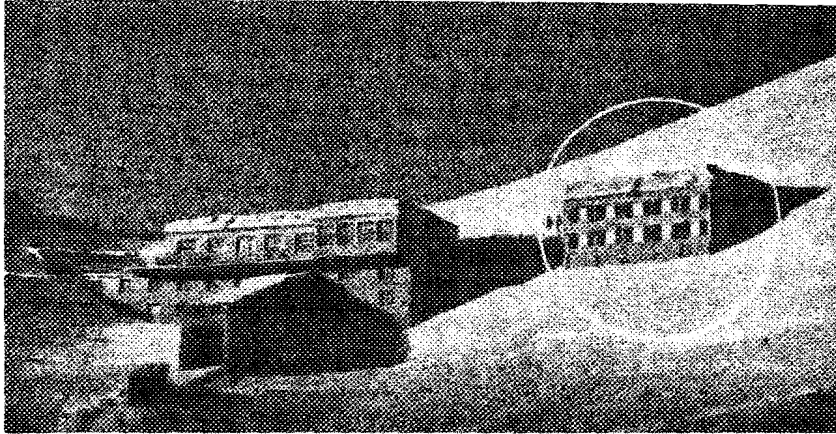
(Note: This list is identical with the first 27 titles under the same heading in "Schnee und Lawinen im Winter 1945/46.")
(N.R.C. TT-62)

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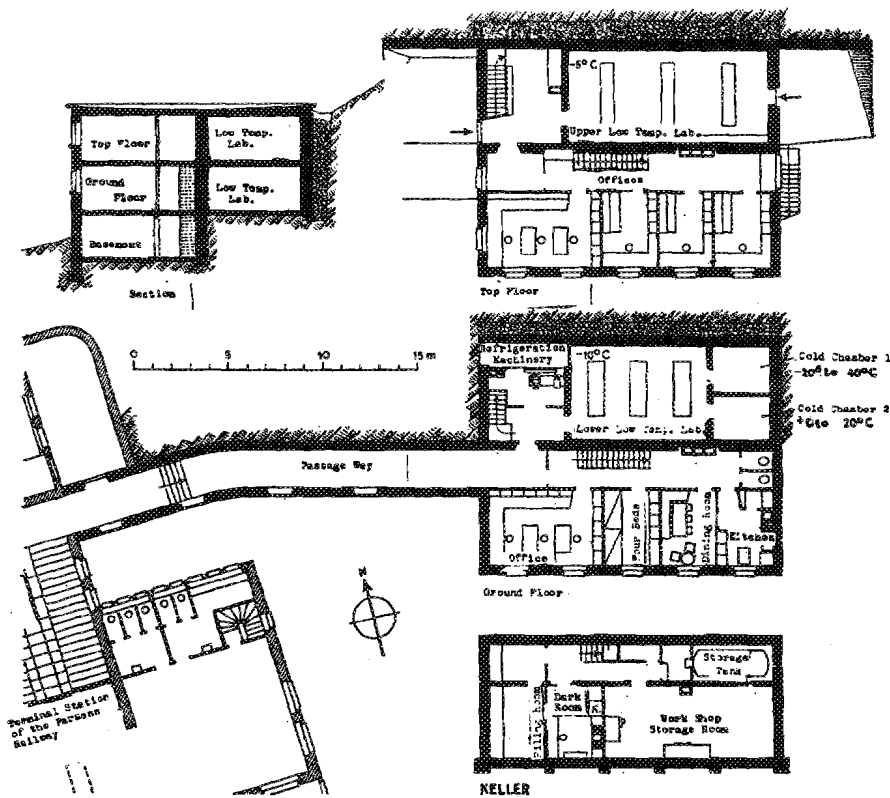
Fig. 1
Tech. Trans. TT-64



The Weissfluhjoch Station of the Davos-Paradise
Railway. Institute Building in the Background.
(Photo by Furter)

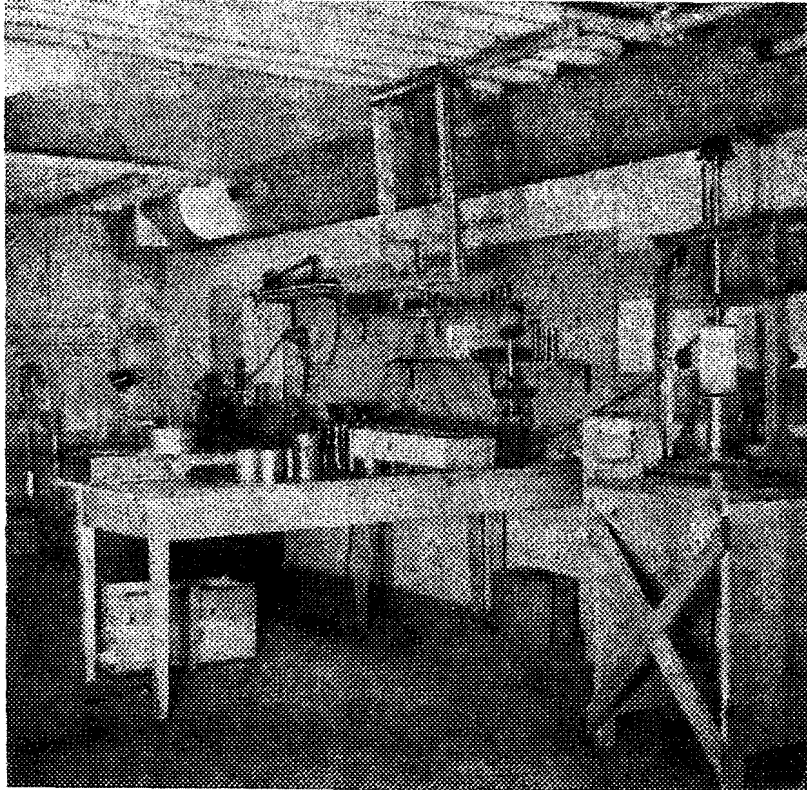


The Avalanche Research Station on Weissfluhjoch, in circle (Picture taken from the South East). (Photo of the Schweizerischen Bauzeitung)



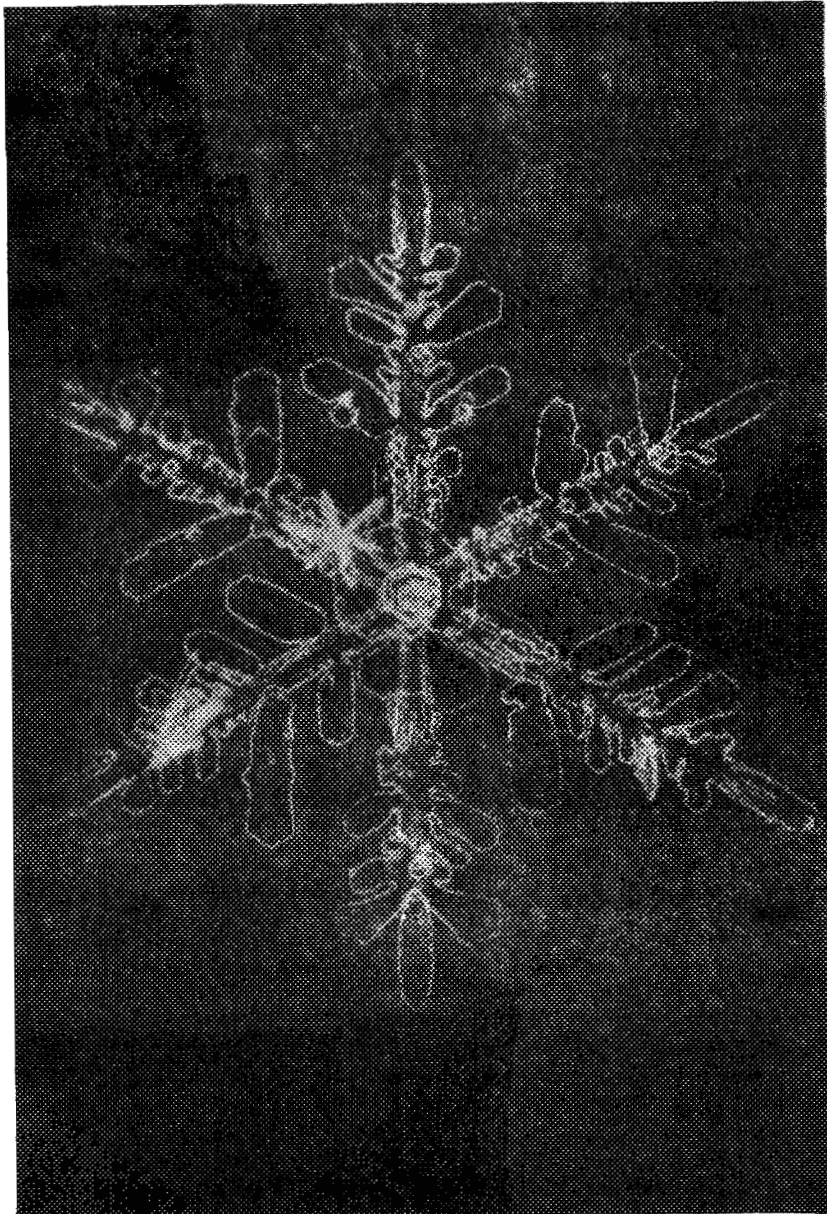
Floor Plans and Section 1:300 of the Research Station on Weissfluhjoch (2668 m. above sea level) ob Davos. (Photo of the Schweizerische Bauzeitung)

Fig. 4
Tech. Trans. TT-64

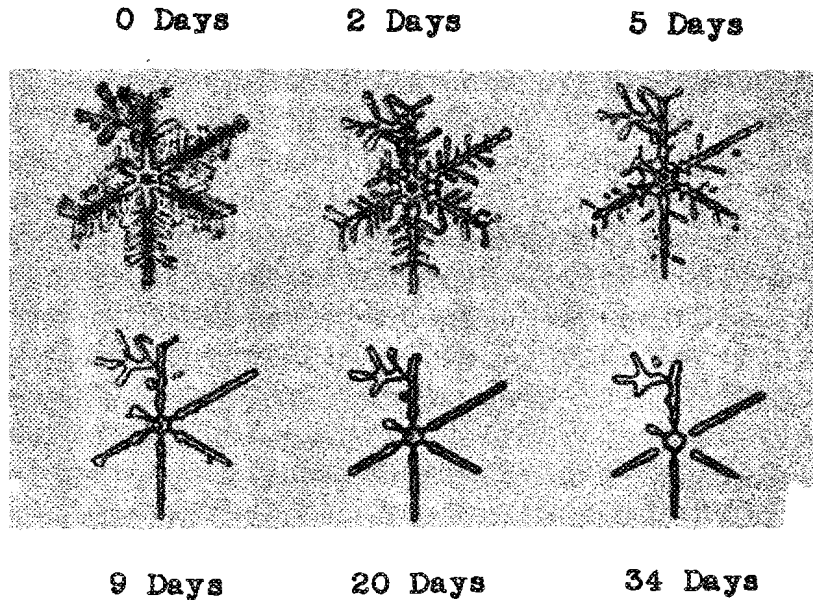


View of One of the Artificially
Cooled Laboratories.
(Photo by Fröhlich)

Fig. 5
Tech. Trans. TT-64



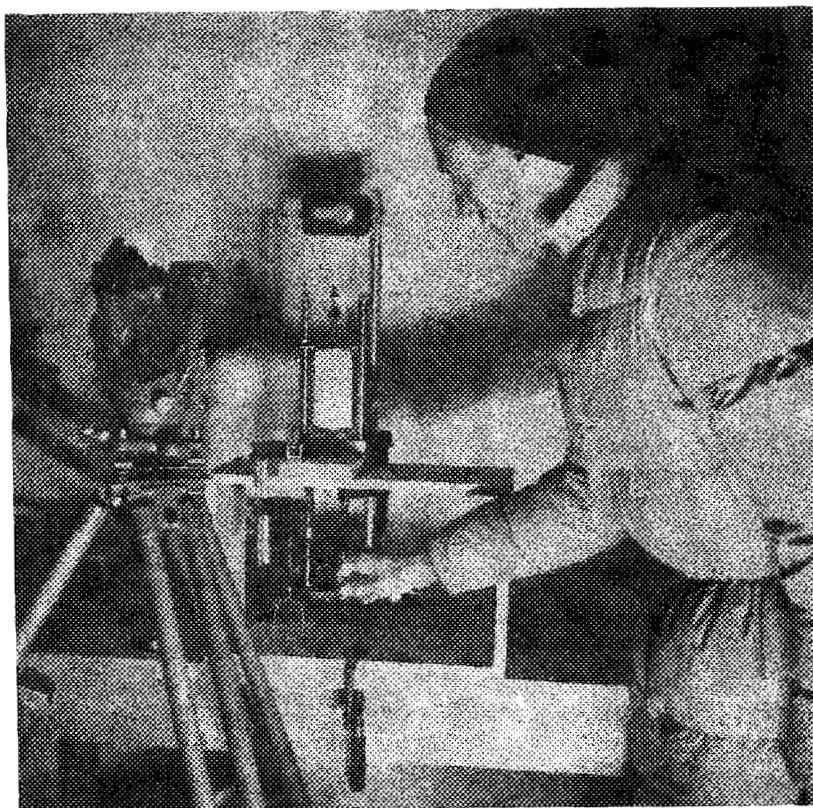
Freshly Fallen Dendritic Snow Crystal.
(Photo by SLF)



Transformation of a Confined Snow
Crystal Over 34 Days at -5° C.
(Photo by SLP)

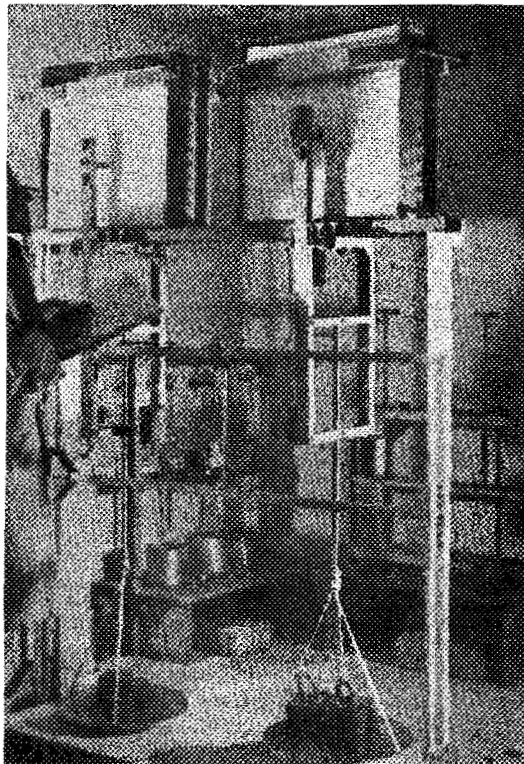
The confined snow flake undergoes a change relative to time in the nature of a surface reduction. Thus it comes about that within the snow-cover there are finely dendritic, feathery crystals as well as fine to coarse grained structural units.

Fig. 7
Tech. Trans. TT-64

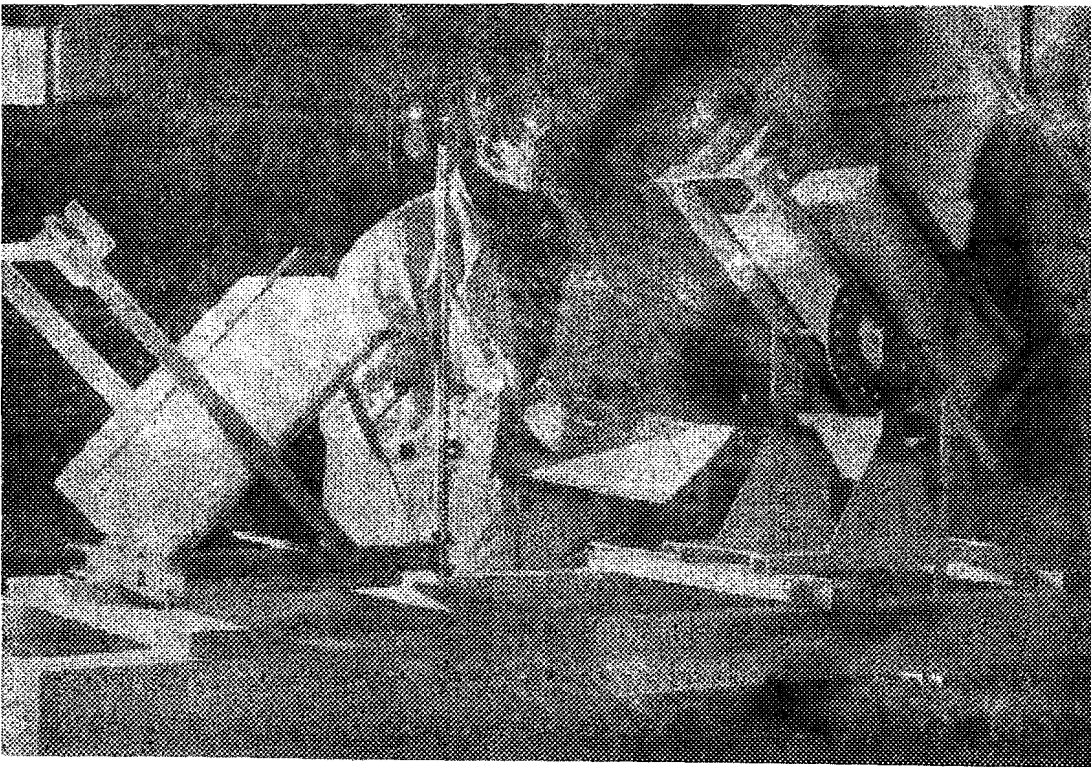


Apparatus with Mirror Reading Device for
Making Viscosity or Plastic Shear Measurements
on Various Types of Snow. (Photo by Fröhlich)

Fig. 8
Tech. Trans. TT-64

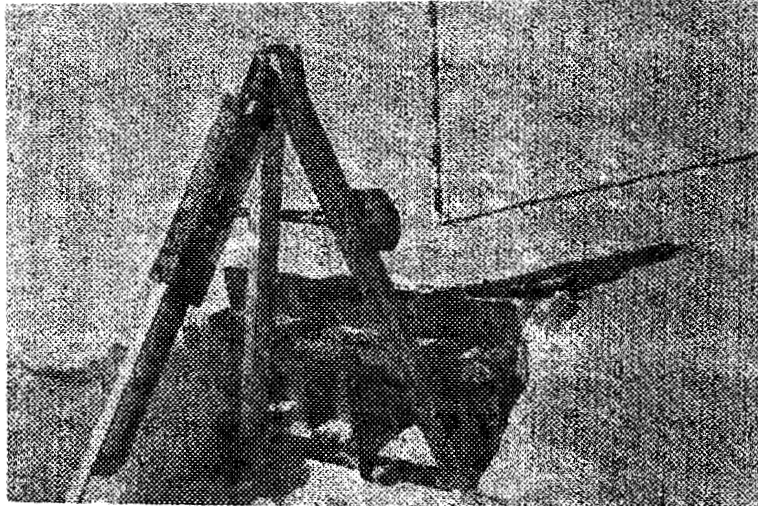


Apparatus for Measuring the Plastic Behaviour
of Various Kinds of Snow. (Photo by NZZ)

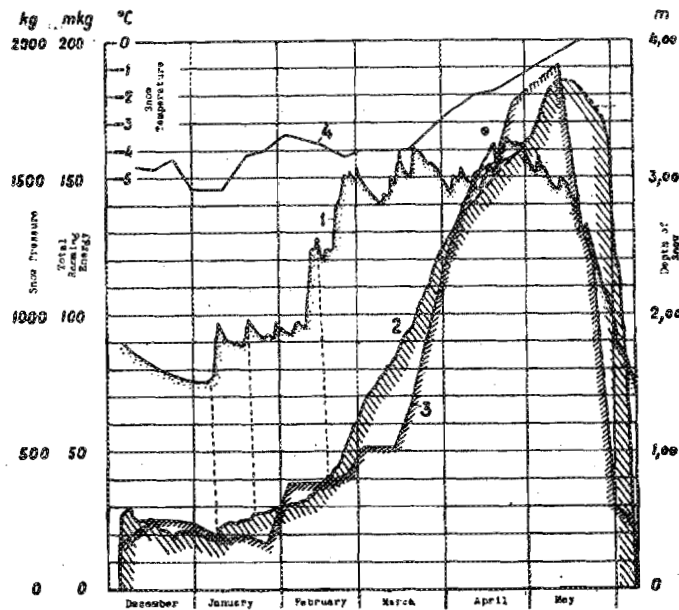


Apparatus for Measuring the Creeping
Motion of Snow. (Photo by NZZ)

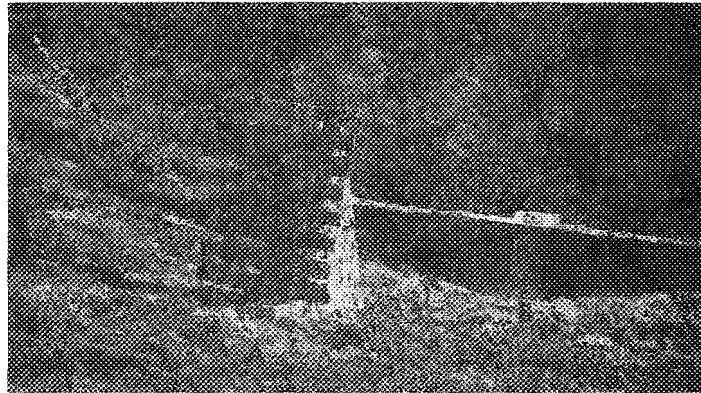
All tilted snow blocks display flowing characteristics. The speed depends on the angle of the base, the condition of the snow and the temperature. The viscosity or plastic shear coefficient of the type of snow being investigated is calculated from these measurements.



Apparatus for Measuring the Pressure Resulting
 From the Creeping of the Snow-Cover on a Slope.
 (Photo by NZZ)



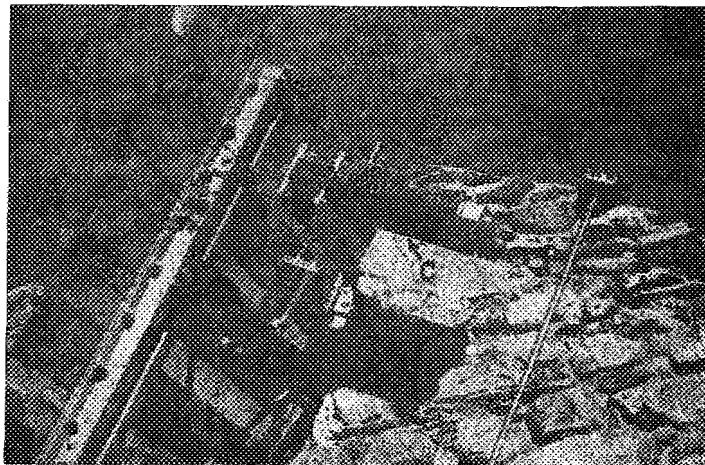
Results of Measurement of Snow Pressure
 (small snow pressure apparatus, Dec. 1936 to
 May 1937). 1. Snow Depth at the Apparatus,
 2. Snow Pressure (normal component N), 3.
 Total Ramming Energy (horizontal test field),
 4. Temperature at Mid-Depth of Snow Cover.
 (Photo by Schweizerischen Bauzeitung)



A. Snow Pressure Apparatus. The Pressure Plate Area 6 m^2 Shaped Like a Gridiron and Supported Universally by Measuring Springs.

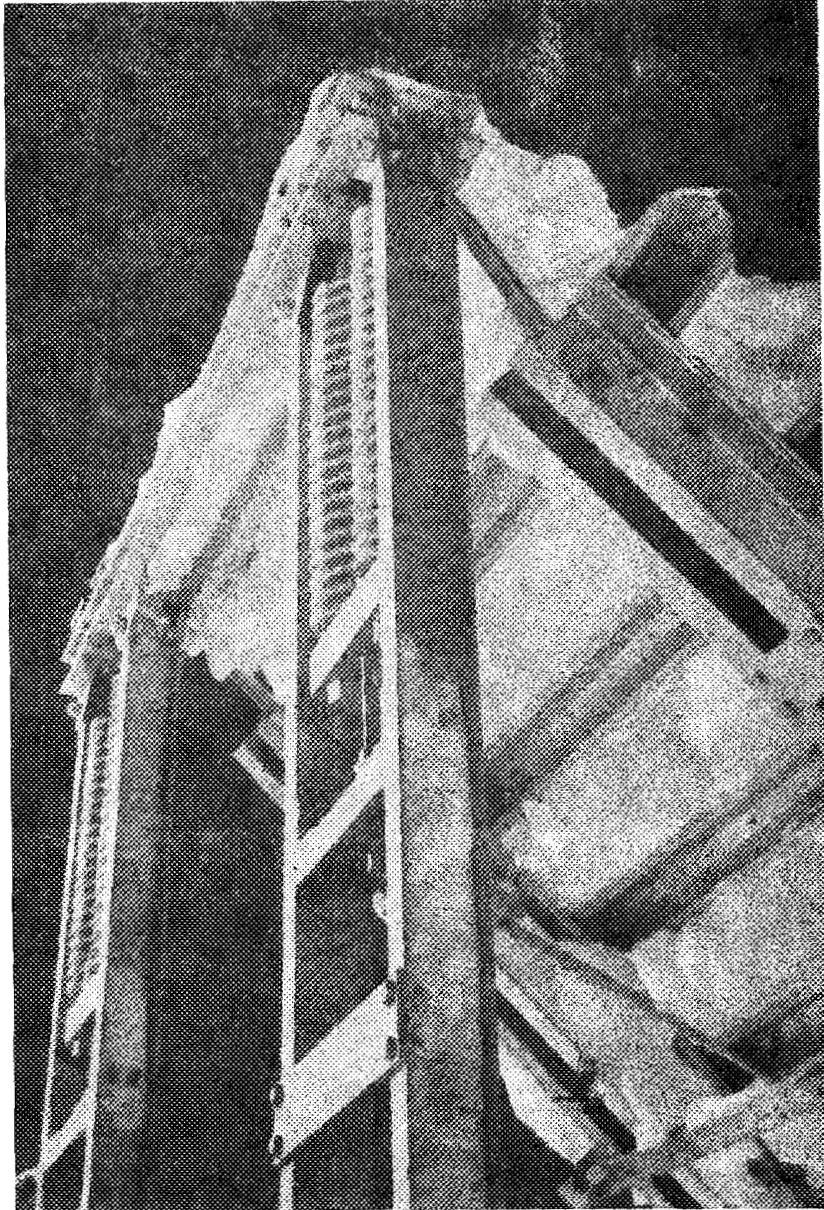
B. Measuring Element (cell) One Metre Wide and Two Metres High. The Measuring Device Consists of a Stack of Ten Superimposed Iron Leaves Whose Deflection is Measured.

(Photo of the Schweizerische Bauzeitung)



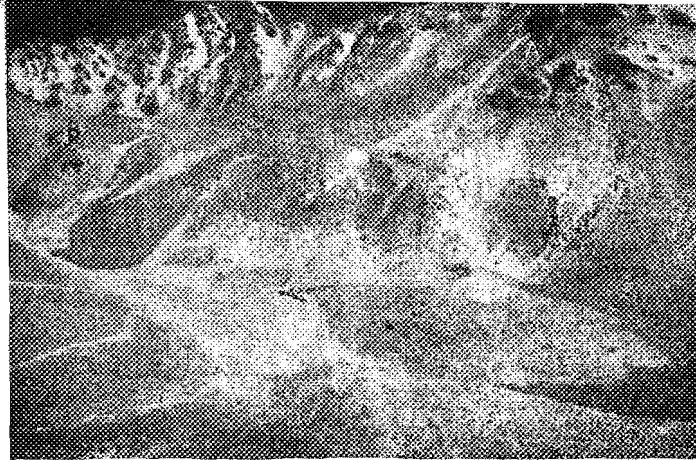
Detail of the Snow Pressure Apparatus. C. Pair of Calibrated Springs at One of the Four Supporting Points Which Transmit the Normal Component of the Snow Pressure to the Stone Pillar (Mauerpfeiler). D. Spring for Measuring and Transmitting the Transverse Force.

(Photo of the Schweizerische Bauzeitung)



Large Snow Pressure Apparatus on Weissfluhjoch.
Pressure Shaft Bent by Avalanche Action.
(Photo by SLP)

Series of Avalanches artificially
Released by Mine Throwers.
A View of Impact
B Detail Photograph
Sauptertal, 31 Jan. 1958.
(Photo of the Schweizerische
Anzeigung)



Detail "from the above picture"; the Dark
Flashes on the Sliding Surface betray the
Formation of Intensive Depth Snow Pockets.
(Photo of the Schweizerische Anzeigung)



Detail of a Wind-Slab Avalanche.
(Photo by HZ)

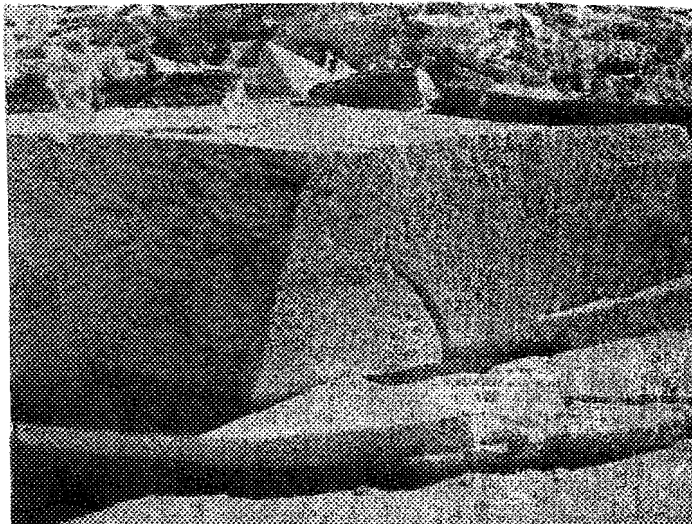


Fig. 18
Tech. Trans. TT-64



Upper Entrance to the Institute, Looking
Eastward. (Photo by SLP)