

High Altitude Laboratories

Physicists and other scientists have found high altitude research laboratories enormously useful as a base of operations for scientific studies that are not normally possible at lower levels. Dr. Korff's article surveys both the existing stations located at 5,000 feet or above and the as yet unexploited sites where high altitude laboratories of the future might profitably be established.

by *Serge A. Korff*

Science has always been international, and where it has flourished it has been nurtured by the contributions of men from all nations. High altitude laboratories similarly are especially beneficial if they are organized on an international basis. High altitude laboratories can serve the scientific community in many ways. Properly set up, they can be helpful in reaching the ultimate objectives of science, the ascertaining of new facts and the better understanding of the way nature operates. We shall in this article discuss those high altitude laboratories which are in the free world, and to which visiting scientists are welcomed. Information about

the laboratories in the totalitarian nations is not publicly available, and since access to them is impossible, it would serve no useful purpose to describe them.

By the words "high altitude" we mean altitudes in excess of 5,000 to 7,000 feet, or say roughly 2,000 meters. Below this altitude there are many large cities, with universities attended by thousands, and with adequate laboratories in physics, biology, and astronomy. Denver and Salt Lake City may be cited in the United States, while Arequipa in Peru, and Nairobi in Kenya are among many examples in other nations in this altitude range. The Mount



The Jungfrau, 13,669 ft. One of the finest laboratories at the 5,000 meter level is located in this region of Switzerland.

Wilson Observatory is situated at about 5,000 feet on a mountain directly above a major city, and the Lick Observatory and the Palomar Observatory are in this same altitude range, on mountains somewhat further removed, but still accessible by good highways from areas where all mechanical facilities are available. At the top of this altitude range also lies Mexico City, where the Tacubaya Observatory and the University actively support vigorous research programs. The Lowell Observatory at Flagstaff, Arizona and the McDonald Observatory, on the 6,850 foot Mount Locke near Fort Davis, Texas are other illustrations.

It is true that there are cities at still higher elevations. Quito, Ecuador lies at 9,000 feet, as does Bogotá, Colombia. Cuzco, Peru lies at 11,000 and La Paz, Bolivia provides the final illustration of the fact that hundreds of thousands of people can spend their lives at 12,500 feet. Each of these four cities has a university. The cities being of considerable size, electric power and mechanical supplies, as well as living accommodations for personnel, are available to such an extent that they may be taken for granted.

Usefulness of High Altitude Stations

High altitude stations are usually thought of in connection with cosmic ray research since this field has witnessed some spectacular high altitude work in recent years. However, it should be borne in mind that many other fields of research will also require such stations. Astronomers wish to locate their coronagraphs at high altitudes and, if seeing conditions are good, also large telescopes for night work. Meteorologists urgently desire accurate and continuous data from high elevations. Glaciologists can use such stations as jumping-off points for glacial studies. Radio propagation studies can make use of high stations and of the long paths between such establishments and other points perhaps at lower levels. Long-distance photography can be experimented with, and atmospheric absorption studies can be made over the long optical paths available. Atmospheric electric measurements, terrestrial magnetism, dust and spore content of the atmosphere,

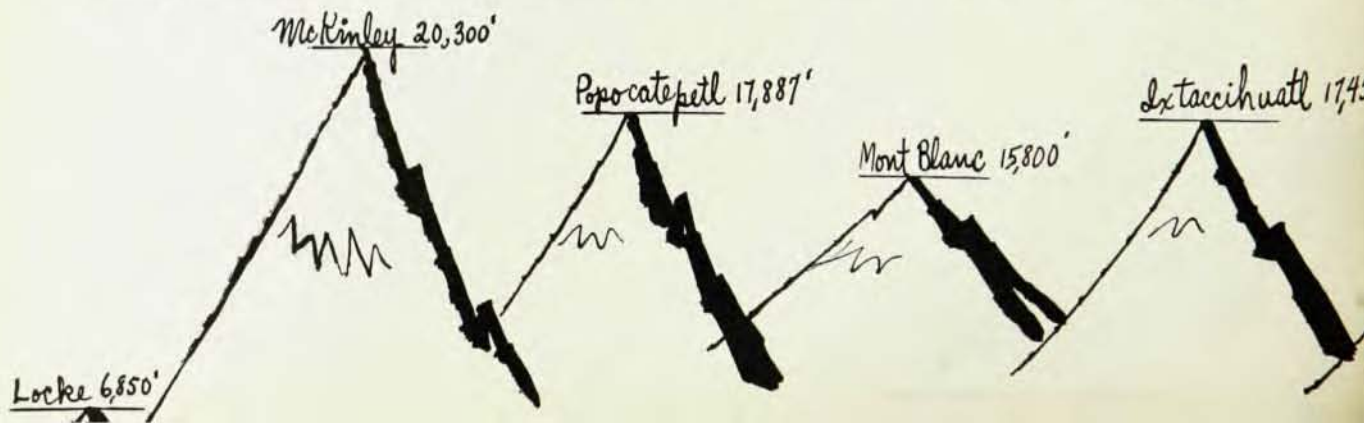
and many other subjects come within the domain of interest of the physical sciences in these stations.

In the biological sciences, many fertile fields of research are to be found requiring such stations. The physiological phenomena observed at high altitudes are many and complex. Effects on ductless glands, on the heart, on blood counts, on respiration, and on metabolism generally urgently require further study. The influence of high altitudes on cells and on microorganisms is only partially understood.

Distribution of Stations

It would be especially valuable to science to have a systematically located chain of high altitude stations available at various points in the world. The distribution should primarily be in latitude and in longitude. The particular nation in which a station is located is of secondary importance, and one might hope that such laboratories would be open to scientists from any nation which might wish to use them.

The principal drawback to the widespread use of stations in other countries at present lies in the various restrictions which certain nations have on the interchangeability of their currencies. Thus, for example, it is difficult for scientists in soft-currency countries to obtain the foreign exchange needed to defray the costs of their visits to the laboratories in hard-currency lands. Considerable duplication of facilities already exists for this reason. We may cite as an example the three stations at about 11,000 feet in the Alps, one in France, one in Italy, and one in Switzerland. These stations are only a few miles apart, and the cost of building and servicing three stations is considerable. Yet because of the exchange situation consolidation and coordination would be difficult. It might be possible for Unesco or some similar organization to arrange a credit clearinghouse and to balance off charges thus incurred, over a period of time, by encouraging return visits, or by multilateral exchanges. The foreign exchange cost of a Swedish scientist visiting Switzerland, for instance, could be offset first by a Swiss visiting India, an Indian visiting Peru, and



finally a Peruvian visiting Sweden. The important thing, at first, is to have a series of stations available, at various altitudes, latitudes, and longitudes.

For simplicity, let us divide up the altitude ranges into groups with approximately a one-thousand meter interval, and let us then see where such stations now already exist. We shall start with the first group, at say 5,000 to 7,000 feet, or about 2,000 meters, and follow with the second group, 9,000 to 11,000 feet, roughly 3,000 meters, the third centering around 4,000 meters, i.e., near 14,000 feet, and the fourth at 5,000 meters and higher.

In the first group, in the lowest interval, coverage is already quite adequate. As was mentioned earlier, large cities with adequate facilities exist. Wherever these cities have universities, and most of them do, there will be libraries, and also machine shops where equipment can be built, stores where parts and supplies can be bought, labor for construction where needed, and usually colleagues at the universities who will be glad to cooperate with visitors and help them make arrangements for living, for setting up their projects, and for getting their work done.

We pass therefore to the second altitude interval, at $3,000 \pm 500$ meters, or about 9,000 to 12,000 feet. In this interval a number of good stations already exist. Doubtless the finest laboratory in this altitude is the Swiss establishment at the Jungfraujoch. This station, at 3,456 meters, is accessible by rail. It, together with the adjacent hotel, provides ample accommodation for visiting personnel. Electric power is sufficiently available for almost any physical experiment, including those which require such large current users as cloud chamber magnets. Ample shop, darkroom, and other facilities exist. The station is connected by elevator with the Sphinx Meteorological Observatory, about 400 feet higher at 11,700 feet. Cosmic ray equipment can be, and has been, operated here too.

Corresponding stations exist in other countries. In the United States, a complete high altitude station exists at Echo Lake, Colorado at about 10,700 feet. Power is available, as is living space for a substantial number of people. The station is accessible by highway open the year around, so that heavy

apparatus can be hauled up by truck, and can be operated over the winter. The distance by road from Denver, the nearest major city, is about 50 miles. An astronomical observatory, its equipment including a coronagraph, operates at Climax, Colorado at approximately 11,400 feet, about 100 miles by road from Denver. This station also has facilities for personnel, ample electric power, and access by road and rail the year around.

In Peru, at about 12 degrees south geographic latitude and almost exactly on the geomagnetic equator, the Huancayo Observatory is located on an 11,000 foot plateau some 12 miles west of the town of Huancayo. The town is reached by rail and road, the observatory by road from the town. Electric power is available. Living accommodations, except for the permanent observatory personnel, are somewhat limited at the Observatory. The station was formerly operated by the Carnegie Institution of Washington, but it has been transferred and is now run by the Peruvian government.

A recent addition to the stations in this interval is the Sacramento Peak station in southeastern New Mexico, at 9,300 feet. Here again, access is by road about 25 miles from Alamogordo, and power is available. The station is under construction, and while accommodations are now primitive, new quarters will shortly exist. The station was designed to supplement the Climax observatory, and will house astronomical instruments in addition to the presently operating coronagraph. It was selected because its observing season is just out of phase with Climax, and weather is usually good at one or the other station.

In France, the Pic du Midi Observatory, accessible by road from Bagnères-de-Bigorre in the central Pyrenees, is located at 9,300 feet. The road ends about 1,500 feet below the observatory, but its continuation is planned to the top. Electric power lines run to the top, and an aerial cableway is available for hauling heavy equipment from the auto road. Living accommodations are adequate for a number of visitors. A coronagraph is regularly operated there and other activities include some conventional astronomy, some cosmic ray work, and routine meteorology. The buildings were built some





years ago, are of stone, and are more substantial than most of the others cited.

Almost exactly at the same altitude as the Swiss station of the Jungfraujoch is the Italian station at Testa Grigia. This station is located on the ridge connecting the Matterhorn and Monte Rosa, on the Swiss Italian frontier. The laboratory consists of a single room for apparatus and smaller rooms for personnel and cooking. Access is by road to Breuil, up the valley of Aosta, and thence by aerial cableway to Testa Grigia. Electric power follows the cableway. Living accommodations are not adequate except for observatory personnel. The third 11,200 foot laboratory in the Alps is in France, just above Chamonix, on the shoulder of Mont Blanc. Access is again by aerial cableway from Chamonix, which in turn can be reached by automobile or by rail. Electric power again parallels the cableway. The cableway does not operate during the winter, and is shut down during storms. Living accommodations are adequate for the operating staff.

In the next altitude interval, centering around the 14,000 foot level, facilities are much fewer and less well distributed. The only regularly operating station is the Mount Evans laboratory in Colorado at 14,156 feet (4,310 meters). Electric power lines do not reach the station, and small generators powered by internal-combustion engines are used. In case of any unusual power requirement, a special

generator would have to be brought up. Living accommodations are primitive, and not more than four persons can stay with comfort in the building. Yet the location is superb, and access is easy over a road paved to within a short distance of the summit and good gravel the rest of the way, the distance to Denver being roughly 65 miles. Denver is visible, and forty-mile optical air paths are easily available. The road is not open during the winter at present, but could be kept open if there were a sufficient reason to warrant keeping a snowplow operating.

At still higher elevations there are no presently operating stations. Many sites have been occupied for varying periods of time, and permanent stations are possible.

Facilities Urgently Required

It is a sad commentary on the small support which science receives today, unless it can be shown to have immediate military or utilitarian results, that there are no facilities available anywhere in the world at altitudes above 14,000 feet, and even at that altitude only one small and totally inadequate station. This is doubly sad, since the possibilities of constructing stations at this and higher altitudes are on the whole rather favorable. Access to such altitudes is not especially difficult.

In the United States, mountain building proc-

esses have played a curious trick. Some fifty peaks of 14,000 feet and above exist, and yet the highest, Mount Whitney in California, is only 14,495 feet. Three of the peaks in this group have auto roads to their summits, Pike's Peak, 14,107 feet, and Mount Evans (both in Colorado), and White Mountain in California, 14,242 feet. Pike's Peak has a cog railway in addition. In Mexico, the Nevada de Toluca, a peak whose summit is 15,120 feet, has an auto road to a point in the crater, at some 4,300 meters. This peak has served also as a cosmic ray observing station, and the establishment of a permanent station there is presently under consideration. Indeed, a project of this nature would be of the greatest value, since it would supplement the stations further north at about the same altitude. The Mexican peak is in the middle of the latitude interval in which the cosmic radiation undergoes its greatest change with latitude. Its longitude is near enough to that of other stations in the Americas so that no large corrections for longitude

effect need be made. Hence it would be a most useful addition to the roster of high altitude stations, and it is hoped that it will be possible to complete it. While it is true that higher peaks exist in Mexico (to be specific, Ixtaccihuatl, 17,454 feet, Popocatepetl at 17,887 feet, and Orizaba, 18,701 feet) and that it is possible to get a jeep up to above 15,000 feet on Popocatepetl, these peaks are more exposed and the technical difficulties of establishing a station greatly outweigh the advantages of the well-sheltered crater of Toluca.

Further north, in the Alaskan ranges, high altitudes are again available, although the difficulties of access are greater. There are four high peaks, Mount McKinley, 20,300 feet, Mount Logan, 19,850 feet, Mount Saint Elias, 18,008 feet, and Mount Sanford, 16,200 feet. Of these, Saint Elias and Logan have never been seriously considered, for access to their bases is difficult, and all equipment would have to be carried up by hand. McKinley has seen a number of cosmic-ray expedi-



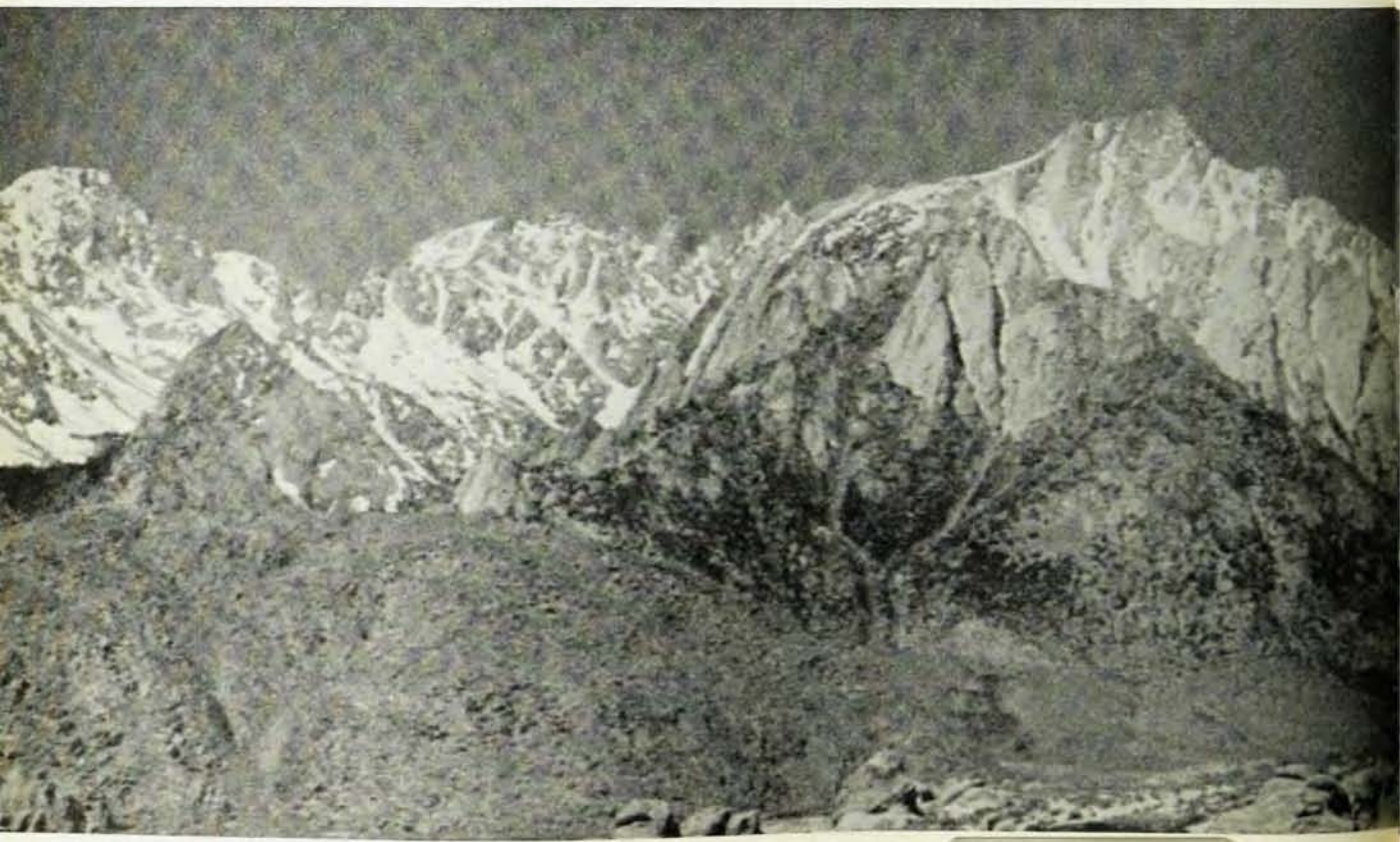
The two highest known mountains in the world are Mt. Everest, 29,002 ft. (opposite page) and K-2 (otherwise Mt. Godwin Austen), 28,250 ft. While it is not immediately practical to consider these as sites for high altitude stations—particularly since they have never been successfully climbed—there are mountains in India where laboratories might reasonably be located at lower levels at a longitude about antipodal to stations in the Americas.

tions, and stations up to Denali Pass, at 19,000 feet, have been occupied by such observers. However, the problems of building a permanent station there are formidable, and the storms are such that access would be denied for long periods. The technical difficulties of mountaineering on this peak are considerable. No road comes within twenty miles of the base. Supplies can be dropped in from the air as Bradford Washburn has demonstrated, but the difficulties of a permanent station there remain formidable. Mount Sanford is an easier climb, and its base is more accessible. Hence it seems the most likely spot, should a high station in Alaska be decided upon, even though it is not quite so high.

In the southern hemisphere, high altitudes are available. In the Andes, there are some two score peaks over 20,000 feet, and the highest, Aconcagua, is 23,800. However, over 20,000 feet, mountaineering difficulties become extreme. No roads exist, and everything has to be carried by hand. The highest point accessible by mule is the summit of El Misti, in Peru, 19,200 feet. This station was occupied in the early days of the century by a meteorological station of the Harvard College Observatory, of the branch then located at Arequipa, thirty miles west. Arequipa is a town of some fifty thousand persons, at an altitude of about 7,500 feet. From Arequipa, an auto road goes about ten miles, but the rest of the journey is by muleback. The summit has been used for cosmic ray observations on three occasions, by A. H. Compton and his group in 1931, by S. A.

Korff in 1934, and by N. Hilberry in 1940. The construction of a shelter at the summit is feasible, and the auto road could be continued to about 16,000 feet without great engineering difficulties. This would leave a four-hour mule ride to the summit, which is not out of the question as loaded mules could get up and back in daylight.

Considerable altitudes are accessible by rail. The Ticlio station of the Central Railway of Peru is at 15,616 feet, and the La Cima station is at 15,805 feet or 4,817 meters, so that heavy equipment could be carried to this level and supplied indefinitely. The Crucero Alto station of the Southern Railway of Peru is at 14,688 feet. Neither station today is much more than a building, but at least buildings and access do exist. Both stations have been occupied by cosmic ray expeditions, Ticlio by Korff in 1934 and Crucero Alto by Neher in 1931. The Morococha mine of the Cerro de Pasco Copper Company in Peru is at about 14,880 feet, with abundant electric power, access by rail and road, and living accommodations. The main mine at Cerro de Pasco is a trifle lower, 14,200 feet, and again it would not be difficult to construct and maintain a laboratory here. Other mines in southern Peru and western Bolivia also are at similar altitudes, and most mines are accessible by road or rail and have electric power and living facilities for personnel. For example, Collahuasi, at 15,800 feet, is also accessible by rail via the Antofagasta and Bolivian railroad. Again, mines usually have labor, supplies



California's Mt. Whitney, 14,495 ft. is the highest point in the United States, but even so is no more than

for building and construction, and mechanics for equipment installation, as well as varying amounts of supplies for construction and testing of technical apparatus. Since Peru already has the Huancayo station at 11,000 feet, a high station would be of the greatest value in addition.

Considering next a change of longitude, there are high peaks in the equatorial zone in Africa. The summit of Kilimanjaro, almost exactly on the geographic equator and not far from the magnetic equator, lies at 19,710 feet, and Mount Kenya, a hundred miles north, is 17,040 feet. However, Kenya is probably more difficult technically. The Uganda railway reaches 8,300 feet. A Dutch astronomical station on the slopes of Kilimanjaro was last year being seriously considered and by now is probably useable. It will not be at so high an elevation as possible, but will provide a good base for operations. Both mountains stand on a plateau whose level is about 5,000 feet. The nearest town is Nairobi, accessible by rail and road.

In the Alps, with three stations at the 11,000 foot level already in operation, it appears doubtful if higher ones will be built in the near future. There are peaks which reach the 14,000 foot level, the Matterhorn being 14,770 feet (4,505 meters), Monte Rosa 15,200 (4,638 meters), and Mont Blanc 15,800 feet. But the Alps receive quite a heavy snowfall, and the difficulties of building and maintaining a station at extreme altitudes, and of reaching it in winter, are considerable. Indeed, of

the three 11,000 foot stations, only the Jungfraujoch is accessible the year around, and this only because it is reached by a railway inside the mountain. In the Caucasus, Mount Elbrus reaches 18,471 feet, Mount Kazbek 16,541. It is reported that a laboratory is being operated there, but this station is not accessible to scientists from this part of the world, nor is any accurate information available about the facilities.

In New Zealand, the highest peak is Mount Cook, 12,340 feet, but this peak is heavily glaciated, and no high altitude station has been considered. In New Guinea in the Queen Wilhelmina range Mount Carstens reaches up to 16,404 feet, but here access is so difficult that this range again has not been seriously discussed, although the climate is favorable, and the location one which would be potentially valuable if the access problems could be overcome.

India provides about the only remaining possible group of mountains where a high altitude station could be installed and operated. It would be most valuable to have a station at the 14,000 foot level or higher if possible, in this longitude, for it is about antipodal to the stations in the Americas. It is to be hoped that the government, or some of the wealthy citizens of this country, will make such a station a reality.

Serge A. Korff, who has written other articles for *Physics Today* in the past, is professor of physics at NYU. He is thoroughly familiar with mountains, high altitude laboratories, and cosmic rays, having gone on a number of treks in search of some happy blending of the three.

