the exigencies of the war is not a patch on the amount of absolutely untapped forests which exist in the world at large. Mr. Stebbing has brought to our notice one of the enormous forest regions which is still comparatively open to exploitation, and there are others in other parts of the world where one is surprised that hitherto no attention to forestry or timber-cutting has ever been given. I know one very extensive region in South America, south of Valdivia, where there are untapped forests almost covering Southern Chile. And, moreover, that is country which is unusually well supplied with large and rapid rivers, penetrating the forests, which would afford every facility for exportation. I am speaking of a time about ten or twelve years ago. Since those days something may have been done, but at the time when I was in that part of the world the reason given me, why no use whatever was made of those forests, which are full of valuable timber including a great variety of ornamental woods, was that it was absolutely cheaper for Chile to import lumber from Norway than to cut its own wood. That is a state of things that I imagine cannot last long. There were very few places that I can remember where timber industry was attempted. In Tierra del Fuego there were one or two busy saw-mills ; another flourished in a colony on the Atlantic coast where a really good business was instituted, at a Roman Catholic Missionary Station. The mission was supported entirely by timber-cutting. Incidentally, Mr. Stebbing has reminded us that we may hereafter wish to institute a regular trade with Archangel and that ice-free port, Alexandrovsk. So that we were not much too soon when, as a Society, we called the attention of the Government to the importance of retaining command of Spitsbergen ; and if we are to preserve free communication for the import either of timber or other produce, we must certainly retain command of that route and hold those northern seas from Spitsbergen. I will ask you to join in thanking Mr. Stebbing for his excellent address.

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# THE POSSIBILITY OF AERIAL RECONNAISSANCE IN THE HIMALAYA

Dr. A. M. Kellas

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IF conquest of environment constitutes progress, the introduction of the aeroplane marks a great advance in the history of mankind. The Royal Geographical Society is for the present mainly concerned with the evolution of aerial navigation from the point of view of its use in exploration, and, when normal times arrive, may almost certainly look for a rich harvest in that direction. Allowing for the certain development of speed, safety, and weight-carrying capacity of aerial machines, how practicable explorations such as the following would appear from the purely scientific point of view ! The aerial traveller might start from Gibraltar and explore the territory of the fanatical tribesmen of Southern Morocco with impunity, obtaining material for mapping the country and the western Atlas Mountains. From Egypt as base he might survey thousands of square miles of the Eastern Sahara; from Aden and Egypt he might investigate the deserts of Arabia; from the coast of the Guianas he might fly over the malarial jungles to the cordillera of Southern Venezuela, and perhaps discover a convenient landing-place on the Tumac Humac; he might survey the desert of Gobi from the Siberian Railway; or, finally, he might get a bird's-eye view of such portions of the polar area as are not the "Home of the Blizzard."

A few tracts on the Earth's surface, however, might seem to offer special difficulties. The illimitable forests of Brazil, the hurricane lands of Western Antarctica, the immense height and icy crests of the Himalaya, might cause the most adventurous airman to pause before attempting their exploration. It is with the last-named area that we are concerned this afternoon, and the subject for consideration might be stated as follows: Is it possible to fly over the Himalaya, and if so, what arrangements could be made for aerial reconnaissance of that region?

With regard to the possibility of flying over the Himalaya, the only point which need be considered at this stage would be the height to which an airman would have to rise to cross the main range—the Great Himalaya—which, as seen from the plains to the south, tower up as a gleaming wall of snow and ice. Consider, first, direct passage over the range. Excepting the peaks above 24,000 feet, of which only about eighty are so far known, and assuming that an airman would fly as a rule at least 1000 feet above the mountains to lessen the danger due to the winds that often sweep across the ridges, then it might be said that an airman could cross the range when flying at from 23,000 to 25,000 feet without having to deviate more than 5 to 10 miles from his direct alignment on account of great peaks. Burrard's interesting tables and charts show this conclusively. He gives:

| | |
|---|---|
| Peaks above 27,000 feet ... ... ... ... ... ... | 6 |
| " " 26,000 feet ... ... ... ... ... ... | 17 |
| " " 25,000 feet ... ... ... ... ... ... | 50 approx. |
| " " 24,000 feet ... ... ... ... ... ... | 80 " |

Assuming 23,000 to 25,000 feet as an approximate elevation which might be required for clearing the main range, there is, from the argument adduced in a former paper by the author, which included considerations of physiological difficulties involved in climbing the loftier Himalaya, no reason to doubt that an airman could negotiate that altitude satisfactorily (see *Geog. Journ.*, 49, p. 26, Jan. 1917).

Without going into the arguments brought forward in that paper, the fundamental facts may be summarized thus:

1. Altitude sickness (*Hypoxæmia*) is due to a deficiency of the oxygen required for promoting normal tissue oxidization.

2. The oxygen supply available varies directly with the atmospheric pressure which at sea-level will on the average balance a column of mercury 760 mm. high. At the top of Mount Everest (Chomo Langmo,

29,141 feet) the pressure is nearly 250 mm. at 0° C., only about a third of an atmosphere. These numbers do not however represent relative alveolar oxygen pressures (*loc. cit.*, Table VI., p. 42), which would be approximately one to a fourth and not one to a third.

3. Experiments in air-chambers and the experience of balloonists indicate that ascents above 25,000 feet, where air only is breathed, would be hazardous. It was pointed out, however, that this conclusion did not apply to the climber, whose alveolar oxygen pressure, *i.e.* the pressure of oxygen in the ultimate ramifications of the lungs, rose as he ascended, relatively to his carbon dioxide alveolar pressure, although both naturally steadily diminished with increase of elevation; at the same time his blood suffered an acidosis which aided the diminished carbon dioxide in adequately stimulating the respiratory centre in the *medulla oblongata.* It was pointed out, too, that the number of red blood-corpuscles—which act as oxygen carriers—steadily increased per cubic millimetre if time were given for acclimatization.

The problem of the climber at high altitudes is therefore different in some respects from that of the airman. In the case of the airman the results indicated by experiments in air-chambers would hold during flight if a wind screen rendered the atmosphere immediately round him nearly stagnant. But this would rarely be the case, and the air would tend to get packed into his lungs by his motion, thus raising his alveolar oxygen pressure. It would probably be found, however, that even an airman in first-rate training would feel the want of oxygen if he flew at an altitude of 20,000 to 22,000 feet for some time; and many men might do so at 15,000 to 18,000 feet, or even lower. The airman has the advantage over the climber that he expends energy at a slower rate, the latter doing comparatively hard work in raising his own weight.

4. Experimental work in air-chambers and balloons, during which air admixed with oxygen was breathed, indicated clearly that altitudes higher than the loftiest Himalaya might be reached with proper precautions. Paul Bert breathed such a mixture at a pressure of 240 mm., corresponding approximately to an altitude of 32,000 feet; while Aggazotti breathed a mixture of carbon dioxide and oxygen at a pressure of 120 mm., which would correspond to an altitude of nearly 50,000 feet. These facts should allow airmen to fly at very high altitudes if they are provided with oxygen and proper inhalers. If the height were much above 30,000 feet special care would be required, since two balloonists, Berson and Süring, although provided with oxygen, became insensible at about 35,000 feet.

5. A well-known British airman (Mr. H. G. Hawker) was reported in the Press to have reached 24,408 feet in a Sopwith fighting biplane. Unfortunately I do not know whether the reading of his aneroid was confirmed by a laboratory test after landing, and from my own experience while climbing I confess to doubting the accuracy of any aneroid readings above 20,000 feet, unless so confirmed afterwards.

NORTHERN SLOPE OF WESTERN PART OF KANGCHENJHAU MASSIF, FROM NEAR GYANTSHONA (16,000 FEET).

Unexplored valley in Tibet north-west of Jongsong Peak, showing possible landing-place at 19,000 feet. Note: the picture is taken from 21,500 feet, and there is a precipitous fall to about 19,000 feet beyond the near edge running across the foreground.

6. The maximum height so far attained by any climbers was 24,600 feet, reached by the Duke of Abruzzi's party in the Karakoram Himalaya.

The above summary seems to indicate clearly that there is no physiological difficulty in flying for some time at 25,000 feet if there is a plentiful supply of oxygen and suitable apparatus for utilizing it to the best advantage. As regards the horizontal distance which an airman might have to travel at 23,000 to 25,000 feet, it would as a rule not be greater than 10 to 15 miles, unless he were moving along the range instead of crossing it. There are, of course, exceptional areas with a tangled mass of ridges, where it would be difficult to find a satisfactory landing-place.

It must be pointed out, however, that in order merely to make a transit of the Himalaya it would not as a rule be necessary to pass over the summit of the great range. There are many deep gorges carved by the rivers, several of which rise in the Zaskar and Ladakh ranges to the north of the Great Himalaya. Utilizing passes, which are frequently on spurs of the main range connected with the river defiles, it might be possible to cross the range without rising above 19,000 feet (or less). The gorges of the Teesta, Arun-Kosi, Karnali, and the headwaters of the Ganges, the Vishnuganga, Dhauli, and Bhagirathi can be cited as examples. There might, however, be very troublesome and gusty winds through these gorges at sundown, becoming sometimes of hurricane strength. The practicability of the pass routes for easy flying would greatly depend upon the season of the year.

Any summary of personnel and material must be brief, as the author does not pretend to be competent to deal with many of the practical problems involved. For high altitude work only men of good constitution and in first-rate health and training should be employed. As a slight test of endurance, they might be expected to be able to walk 20 to 25 miles in say eight to ten hours over a rough ground without serious fatigue.

A factor in design would be to make a machine, the wings of which could be lowered and raised, or temporarily dismantled; otherwise the wind might often upset the stationary plane, which in many situations could not be screened. As I have previously pointed out, however, a gale of 50 miles per hour at 19,000 feet has only about half the lifting effect of wind of the same velocity at sea-level.

Preliminary experiments should elucidate difficulties connected with wind, clouds and weather; possibilities of alighting and starting at high altitudes; and possibilities of acclimatization to reduced pressures under different conditions.

The wind would vary greatly with the season of the year. During the monsoon, which may last from the middle of June to mid-September, the airman would probably experience a strong southerly wind in many regions, which might last from sunrise to sunset, and in certain districts, as in Sikhim, would help the transit of the range from the south if an early start were effected. With the first snows of winter, which may fall any time in September or October, the dynamic aerial equilibrium between the atmosphere over the Tibetan plateau and that over the plains to the south of the Himalaya may become much more stable. Mr. Freshfield, in his first near circuit of Kangchenjunga, carried out in September 1899, expressly states that they were not troubled by wind, and had many cloudless days. This fine weather was apparently due to the heavy fall of snow of about a metre in depth in north Sikhim and southern Tibet on September 25 of that year. The author has never experienced weather of that type during the monsoon, when clouds frequently form on the mountains at from 5 to 10 a.m.; but has enjoyed a few fine days, with considerable wind disturbance, however, after a fall of over 2 feet of snow in September 1909.

From these experiences, and information given by various writers, it would appear that the months of October and November, after southern Tibet has had its area under snow greatly increased, would probably be finer weather for survey work than during the summer. There might, however, be keen winds, for I can hardly conceive of the air remaining quiescent over such a lofty region for any length of time. My own experience in certain areas during the monsoon has been that it was not only windy all day, but sometimes during the whole night as well. One great disadvantage of October and November would be the obscuration of mountain contours by the mantle of fresh snow, which might make photographs of secondary value. The temperature of the air, also, would be low, which would be disadvantageous for camping or flying. It must be noted, however, that the experiences of the British Mission to Lhasa in 1904, and those of Dr. De Filippi in 1914, indicate that under suitable conditions exploration of the Himalayan area may be effected towards the end of the year.

The month of September, when the monsoon is abating, and the month of May before it begins, might be found best of all. In the former month, one would have a moderate atmospheric temperature, possibly clear days, the snow very little below the summer level and frequent fine cloud effects. But while cloud banners and curtains would give magnificent scenic displays, they might not be appreciated by the airman anxious to secure photographs for survey work. The problem of flying through cloud will have to be faced and solved. If an aerial trans-Himalayan post were arranged from Calcutta to Lhasa, and thence to Pekin and Tokyo, the ascent through great cloud strata during the monsoon might cause trouble if the horizontal position were not maintained. From the hills north of the Pindari river I have looked south to the foothills, where cumulo-nimbus seemed piled on cumulo-nimbus to a minimum thickness of 25,000 feet. Strong electrical discharges seemed to be taking place between the cloud layers, and the airman in such a system would be in an awkward plight unless he could maintain his horizontal position. Such accumulations may however be exceptional, and it is possible that even in the monsoon the airman would generally be able to rise above the cloud strata, which, as a rule, might not be more than a few thousand feet thick.

From easily accessible summits on the northern flank of the Great Himalaya, one has often looked on a rolling sea of mist, the height of which seemed to vary from 20,000 to 25,000 feet. But cloud strata of considerable density may form at and above 30,000 feet. Sometimes, within half an hour of sunrise, peaks of 25,000 feet which have for a few minutes been quite clear became enveloped in a cloud bank extending thousands of feet above them.

The problem of landing and starting at great altitudes is of considerable difficulty. Landing on snow would be easy on many mountains, but to get off again would be another matter. The airman surprised by engine stoppage might be expected to look out for the biggest and smoothest snow-patch on which to effect a landing. On many mountains of the Himalaya there are large fields of snow almost inaccessible; and once landed an aviator might find himself marooned. But the writer happens to be acquainted with many places above 20,000 feet where an aeroplane could land upon snow with a possibility of getting off again. On Chumiomo, at about 22,400 feet, it might just be possible. On the northern Jonsong saddle there is a beautiful situation for camping at about 21,500 feet, and another at 24,000 feet, on both of which landing would be practicable. On Pawhunri near the summit (23,180 feet) it would not be advisable to land, although easily possible at 20,000 feet. The best place I know between 22,000 and 23,000 feet for carrying out experiments on landing and starting at moderately high altitudes is the summit of the Kangchenjhau (22,700 feet), near the Tibetan border about 100 miles north of Siliguri (which is on the plains at the edge of the hill region), and about 600 miles due north of Calcutta. As an airman could probably fly from the plains of Siliguri to the base of the mountain in less than two hours, and ten days would be considered fast travel on the roads, while most travellers would take about fourteen days, allowing for difficulties of coolie supply and transport, the annihilation of space and time by aerial navigation is well exemplified.

Photographs of this mountain show its suitability for experiments of the nature suggested. The first shows the whole massif, and indicates that the main summit is a snow-dome at the end of a precipitous ridge. Note the great line of precipices on the north. The second shows the south face, also nearly perpendicular. The easiest way up is from the east; and while it is easy to walk up if the snow is in a satisfactory condition, it is hardly a convenient route for bringing down a derelict aeroplane. The summit is a snowy plateau with an extensive view commanding on the south the bulk of Sikhim, and on the north a great part of southern Tibet. It slopes gently in three directions to the edges of precipices, but extends westwards after a slight dip as a long ridge. Probably it would easily give 250 to 300 yards or more as a starting run.

The state of coherence of the snow might cause trouble: very low temperatures give a powdery snow peculiarly intractable, similar to that which Scott encountered on the Antarctic Barrier on his last journey. Until 8 to 10 a.m. or thereby in September the surface is covered with a thin crust, which will easily bear a man, but presumably not an aeroplane. The snow is deep and comparatively soft beneath the surface film—an ice-axe can usually be driven in up to the hilt without difficulty—and therefore would require either rolling or compressing with a heavy stamp, until firm enough to give the necessary resistance to the moving plane.

A further complication which might cause trouble during a preliminary experiment is want of acclimatization to high altitudes. The airman flying from the plains of India to the summit of the mountain would be at a grave physiological disadvantage as compared with the climber reaching the top from a camp at say 19,000 feet. In the case of the climber, as indicated in the previous paper and already referred to, his alveolar oxygen pressure would be nearly a maximum for the altitude, and his blood would have undergone such an acidosis that washing out the carbon dioxide by the rapid breathing which necessarily occurs at high altitudes during exertion, would not cause a tendency to faint, the altered blood-condition affording the necessary stimulus to the respiratory nerve centre. He would also have greatly increased the number of his red blood-corpuscles per cubic millimetre by becoming approximately acclimatized at 19,000 feet. In the case of the airman flying from sea-level, this would not be the condition of affairs. He might reach this ridge near the Tibetan border within two hours of leaving the plains at Siliguri, and would probably be using oxygen for the last half-hour. On landing on the summit and stopping the inhalation of oxygen, he might feel quite well while quiescent; but if he carried out any hard work, as in compressing the snow, he might be attacked by mountain sickness, and might even faint if he persevered in his efforts.

It is quite possible that by repeated trial flights from sea-level to 22,000 to 25,000 feet, using oxygen only when absolutely necessary, the alveolar epithelium might be educated to make the most of a minimum supply of oxygen, but while experiments in this direction are desirable, it would be unnecessary to make them exhaustive at this stage, as the proper investigation of the effect of preliminary high flights, and of landings at great heights, with and without attempts at partial acclimatisation to altitude, would involve a somewhat complicated series of researches, the nature of which was vaguely outlined in the previous paper.

An airman who had camped for some time at 15,000 to 19,000 feet would probably be in a much better condition to undertake serious work above 22,000 feet, and experiments might be carried out both from sea-level and the latter altitudes. It is obvious, however, that any airman alighting at 22,700 feet for experimental purposes, should be supported by climbers, who might have a tent pitched on the summit, and have prepared the snow for the aeroplane, and the path for the take-off run. The climbers' camp could be on rock *débris* at 19,000 feet only about a couple of miles from the summit; and they might from such a station form a camp on the top of the mountain, throwing up a large snow-bunker to the south, the direction of the prevailing wind from May to October. In such a camp it might be possible to carry out experiments on acclimatization to high altitudes, and find the diet most suitable for mental and physical work above what is generally regarded as the maximum height for permanent acclimatization (17,000 to 18,000 feet).

As mentioned in my first paper to the Society (*Geog. Journ.*, September 1912), the mental inertia above 20,000 feet is considerable, and there is a distinct dislike to carrying out work which involves a continued mental strain, such as estimation of red and white corpuscles, etc. I am confident, however, that such estimations can be carried out at altitudes above 23,000 feet, if the worker is in first-rate training. Experiments during a fortnight to a month at 22,700 feet would extend the results obtained by Haldane and his collaborators on Pike's Peak (14,109 feet) and by Barcroft and his co-workers on the Peak of Teneriffe and Monte Rosa.

It must, however, be clearly indicated that camping for a prolonged period above 22,500 feet, which one regards at present as considerably higher than the limits of permanent acclimatization, is not to be carried out without careful consideration and preparation. A week would probably be safe enough in the case of a trained man thoroughly acclimatized at say 17,000 to 19,000 feet and provided with satisfactory food. A prolonged sojourn might, however, result in gradual degeneration of nerve centres due to deficient oxygen-supply, and if deterioration proceeded beyond a certain point, it is questionable whether it could be properly remedied after descent; that is to say, the mental ability might be permanently diminished. The experimenter camping at high altitudes would therefore do well to test his mental and physical capacity daily. The former could be readily noted by finding the time required to carry out a complete blood-count, or to perform long arithmetical and algebraic calculations. Barcroft, in a suggestive paragraph regarding apparent temporary changes of entity due to altitude, says, "At Col d'Olen (10,000 feet) I have heard two clever and distinguished physiologists pause to discuss whether or no 4 times 8 made 32." I cannot state that I have observed anything of this kind at 20,000 feet, the highest elevation at which blood-counts were made in the Himalaya; but it is possible that the time taken was excessive. The summit of the Kangchenjhau is admirably situated for keeping the physical capacity in good order, as a walk for about 2 miles along the ridge is possible without descending much (if any) below 22,000 feet.

As a preliminary to the above, a base camp might be chosen to the north of the main chain between the Great Himalaya and the Ladakh range at an altitude of from 15,000 to 17,000 feet. Such a position would offer great advantages. The average height of the trough between the main chain and the Ladakh range is probably above 14,000 feet, or even 15,000 feet, which would give a useful pedestal from which to rise to over 20,000 feet when surveying. There are many comparatively flat areas which would make landing-places after preparation. The advantages of acclimatization at such an altitude would be considerable. Airmen in thorough training should require very little oxygen below 22,000 feet, if properly acclimatized at 15,000 to 17,000 feet. The summer weather to the north of the Great Himalaya is quite different from the monsoon weather south of the mountains. Although the crests of the main chain may be enveloped in mist after 6 to 10 a.m., a few miles to the north the sky may be quite clear (cf. *Geog. Journ.*, September 1912). The mists come up from the south, and even during the monsoon if ascents were made at dawn, one or two hours' survey work might be possible before the mountains became seriously obscured.

The problems to be solved are complex, and the territory to be investigated very extensive, so that the time required for even a macroscopic survey would be considerable. At present we are unacquainted even with the east and west extensions of the Great Himalaya itself. In the west we do not know whether the range ends with the Nanga Parbat (26,620 feet) group of mountains east of the Indus, or continues west of that river; and we are equally ignorant of its eastern extension beyond Gyala Peri (23,460 feet) and Namcha Burwa (25,445 feet) where the Brahmaputra breaks through the chain. According to Kingdon Ward the main chain probably bends south-east and becomes the Irawadi–Salwin divide; but any discussion of the geographical problems still to be solved in the development and relationships of the immense crustal folds of which the Great Himalaya forms the chief would unduly lengthen this paper, and cannot be considered in the present communication.

Before the paper the CHAIRMAN said: Dr. Kellas, who is to read the paper on this occasion, is no stranger to this Society or to these meetings. He has unique experience in two sets of interests that are very seldom found together. He, as a great mountaineer, spent much time in climbing in the Himalaya and has ascended almost as high, if not higher, than any other Englishman. He has been in the upper regions of the atmosphere, so far as terrestrial support is available, at heights above 22,000 feet. He is an eminent physiological chemist, and has studied the problem of the influence of highly rarefied air on the human frame, not only in the laboratory but also on the mountains themselves. With this equipment he is particularly qualified to deal with the fascinating question of the probable use of aeroplanes for making reconnaissances in the high mountain regions of the world. At the present time we are looking forward to the close of the war for a great increase in the scientific use of aviation, and there is no department where it could do more than in the inaccessible portions of the Earth's surface, whether in the Polar regions or high mountains. The preliminary conditions which govern the possibility of using this new means of exploration will be developed by Dr. Kellas.

(*Dr. A. M. Kellas then read the paper printed above, and a discussion followed.*)

Admiral MARK KERR (Deputy-chief of the Air Staff): I think the lecture was extraordinarily interesting, but I fear that exploration by aeroplane will not be carried out in the next hundred years. There are several things which render it practically impossible. Exploration on the flat can be done, but you have several things to contend with in the heights. First of all, you would have to have a very large machine to fly the distance and carry the weight that is required. You get a great loss of lift at high altitudes. And in addition to the quantity of fuel you require, there are provisions, warm clothing, and various other necessities for going a long flight and staying in the place for any time that make it absolutely necessary to have a very large machine. Aerodromes for the small machines are not in these days considered to be safe unless there are at least 800 yards each way, so that you can land in any direction, according to the wind. When you come to the large or giant machine you will want an aerodrome even larger, and you will want a hard and smooth surface. We all saw in the one or two aerodromes which the lecturer picked out just now the footprints of the people in the snow. I ask those who have not flown to imagine going into that suddenly on a motor bicycle at 50 miles an hour. I do not think you would want to trouble about stamping the ground down to get off again. You see there are so many things which come in when you have heavy machines. We have difficulties now, and many aerodromes in this country, properly prepared and laid out, cannot be used in the winter because directly they get wet you cannot get off them at all. I was a short time ago in a country a thousand miles off when the enemy came over; our big machines, not as big as we should want for this expedition, could not get off the ground because there had been rain the day before; it was impossible to get speed up to rise because of the mud. You have also another thing to consider—If you start an airman off up into the hills, especially at that height, you get clouds. Instruments are being invented for keeping direction through clouds and keeping level without difficulty, but where you are going and where the cloud is going is quite another thing, and to find an aerodrome, even though you had one on the heights of the Himalayas, is like looking for a needle in a bundle of hay. A ship at sea may meet a current which will take it out of its course 20 miles in twenty-four hours, and that is a big current; in the air you may be 50, 60, or 100 miles out in one hour. There is little known about the air coming across the Atlantic, but I was a few years ago going to fly the Atlantic with a friend of mine, who has since been killed, and I got all the study I could. As far as is known there is a westerly wind at a certain height and an easterly return wind a little above it. When you are up high you cannot see which way the waves are going (and you have to keep a good height for the voyage), so you have not the faintest idea whether you are in the westerly wind which is carrying you from America to England and putting 40 miles an hour on to your speed, or whether you are in the easterly wind which is taking 20 or 30 miles off it; a difference of perhaps 70 miles an hour. Then you may have a pressure or cold snap up north which entirely changes it, and instead of going directly across you are going off south or north of your course. Up to the present we have had no navigation instrument which can give one's position correctly: no doubt that will come in time; but even that would not be accurate enough to enable you to find your way among the peaks of the Himalayas. I am not at all pessimistic on the subject of the air in the future. I have always been extremely optimistic. But there is one thing we have not yet seen our way to cope with, and that is to be able to land a big machine and get it off in a small space. You must have a prepared aerodrome. If you could get a machine to land even at 30 miles an hour, one lump or one rock in the soft ground, if you ran into it, would certainly turn you over. To sum up, you have these difficulties to overcome. You must have a big machine to land in a small space; you have to be able to find your aerodrome; you must have a machine that will land on soft ground in spite of its weight, which does not sound likely, and after that you must have something you can get up again on. So that I fear the air will not help you very much for making a survey up in the tops of the Himalayas for some time. Apart from the other things, we have difficulties now in the winter of getting machines started in the cold. Those are overcome by apparatus which, I fear, we shall not be able to get up in the heights; and the airman would have to fly there without having any of that apparatus. There are also difficulties of lubrication in extreme cold. And when you come to think of it, nobody goes out with a very light heart if he knows that if anything goes wrong there is only one landing-ground within 100 miles, and if he does succeed in landing without breaking his neck he has no hope of having the machine in a fit condition to get up and get home again.

Mr. FRESHFIELD: I regret that Dr. Mill should so early in the discussion have called on me rather than on one of the experts in aircraft we have with us this afternoon. But since I am appealed to as a mountaineer and an old President of the Alpine Club of which Dr. Kellas is one of the most distinguished members, I may take the occasion to give him a word of warning. He will, I think, be well advised not to repeat his lecture before the Alpine Club, for it involves a rank heresy in the view of a body which holds that the final purpose of mountains is to be climbed by our own limbs and without the aid of mechanical appliances. The only plea I can put forward in extenuation of Dr. Kellas' heretical proposal is that a very similar one was entertained by no less a person than the founder of scientific mountain exploration, H. B. de Saussure, as long ago as the year 1785.

In that year, when he was contemplating the ascent of Mont Blanc, which was to be effected two years later, his great friend the Prince de Ligne wrote to him recommending that information on the winds and meteorological conditions at great heights should be gleaned from aeronauts. Dr. Saussure replied in the following terms (26 September 1785): "En gravissant avec tant de fatigues ces rapides rochers (the Aiguille du Goûter) j'enwiois le sort des aeronautes qui s'élèvent à de si grandes hauteurs en retenant commodément assis dans leur gondoles et je pensai même que l'on pourroit tenter l'usage de cette voiture aérienne pour se transporter sur les cimes inaccessibles comme celle du Mont Blanc. Mais je crois que cela sera bien dangereux parce qu'on est sujet dans les hautes montagnes à des coups de vent violents et irréguliers qui pourroient jeter la machine et la fracasser même contre des rocs escarpés et il faudroit d'ailleurs avoir des moyens de direction bien surs pour arriver à des points aussi précisement déterminés."

With this reference, perhaps of some historical interest, I would dismiss the profane suggestion of using flying as a substitute for climbing and turn to the uses of aircraft in mountain exploration, and as an aid in the mapping of the recesses of the great chains. From this point of view I cannot but hold Admiral Mark Kerr's observations are too pessimistic. The distances in most cases between possible good landing-places near the mountains are far from prohibitive. It is not more than 60 miles, as a man flies, from the plains of India to the top of Kangchenjunga, and as much again on to the plains of Tibet or the wide uplands of the Tingri Maidan behind Mount Everest. When last year I discussed possible attempts on Mount Everest after the war with General Rawling, whose loss we so deeply regret, one of the ideas we entertained was that from a base camp established on the Tingri Maidan aircraft might be employed for reconnaissance of the environs of Mount Everest and the unknown ranges of Nepal lying south and west of it. This, I maintain, is a practical proposal, and I will venture to prophesy it will be carried out by some of our younger airmen, to whose skill and love of adventure it would be hard to set limits. There is much encouragement for this view to be derived from what has already before the war been done in Europe. The Alps have been flown over, not once or twice but often. The snowy fastnesses of the Bernese Oberland have been well photographed on the flight. In the case of less well-known and thoroughly explored ranges such flights would be of essential topographical and cartographical service if only as reconnaissances. Every student of cartography knows that the early government surveys in Europe, the French in Dauphiné and round Mount Blanc, the Austrian in Tyrol, and the Russian in the Caucasus either misrepresented or did not represent at all the glacier region. In Western Europe the progress of mountaineering has supplied the information needful for much correction; in the Caucasus this has not so far been the case. Had aircraft been available I and other English mountaineers and our map constructor, Mr. Reeves, would in the eighties of last century have been spared much labour in unravelling the intricacies of the crest of the Caucasian chain. In this task Signor Sella's bird's-eye panoramas taken at great heights were of singular use. To our amusement several of our corrections were ignored by the next German traveller, who naturally preferred the authority of a "survey" to that of "mere climbers."

On the whole then, while allowing that any attempts to alight in the heart of snowy ranges may be an adventure fraught with peril and only to be undertaken in very exceptional cases, I believe that aircraft may prove most useful auxiliaries in the exploration of the undiscovered places of the globe, and, amongst them, of "the storehouses of the snow" which have been hitherto concealed from human eyes.

Major T. ORDE LEES, R.F.C.: The question of aerial reconnaissance in the Himalaya must depend on the possibility of establishing an aerial base at some convenient but considerable altitude. This might be between 15,000 and 19,000 feet. Practical considerations of rarefication and temperature would render it difficult to run an air-station at such altitudes with machines having engines of the normal type. The internal combustion engine has a physiology of its own analogous to that of a human being. In place of metabolism and an opsonic index, it has a volumetric efficiency which drops in inverse ratio to the height attained. Normally its food or fuel consists of sixteen parts of air by volume to one part of petrol vapour. At sea-level air measures 13 cubic feet to the pound; at 15,000 feet the same volume of air weighs only 0·65 lb., and at 20,000 approximately only half a pound. This means, therefore, that the proportion of molecules in a cylinder full of air diminishes relatively as the altitude of the aeroplane increases; hence at 20,000 feet the thermal efficiency of the charge drops to only 50 per cent. of what it is at sea-level, and so the horsepower of the engine is halved. Up to the present no satisfactory method of maintaining the efficiency at high altitudes, by forcing air into the cylinders under pressure, has been devised, and the cost of experiments in this direction would be prohibitive for a private enterprise. It might at first be thought that the loss of horsepower would be compensated for by the reduction of head resistance ("drift"), due to the attenuation of the medium in which the aeroplane is supported, but this would be more than outweighed by the increase in size of the machine necessary to establish the reaction by which the aeroplane flies. The slight increase in density, owing to the reduction in temperature, does not effect a volumetric increase of more than 2 per cent. It is easily demonstrable that it would need very large machines to rise off the ground at high altitudes, and the obvious retort that machines fly daily at 17,000 to 18,000 feet does not dispense with the question at all, as land and rising are quite different propositions from mere flying. There are good grounds for saying that no existing machine would ascend from a plateau at 17,000 feet, and only with difficulty at 15,000 feet. It is, of course, possible to make machines capable of those performances, but only as the result of costly experiments. The requirements of aerial reconnaissance of the Himalayas necessitate prolonged flight at high altitudes—in other words, a long petrol range. As an aero engine consumes about sixteen gallons per hour, the idea of having the base at a low level would seriously curtail the petrol range. There is no doubt that an air-station at 15,000 feet would be a most valuable experimental station, but the cost would make it prohibitive to private enterprise. Forced draught, increased compression ratio, larger aeroplane, bigger and higher-pitched propeller, would be some of the lines of research, while suitable devices for the possibility of landing on snow would need careful and costly elimination. The problem of carburation at high altitudes has, however, already been successfully solved by the Claudel-Hobson and Zenith altitude controls. With regard to landing on snow, it is the common experience of the mountaineers that, in certain lights, every underfeature becomes invisible; experiments in this direction would, therefore, be especially costly. As temperature drops from 1° F. for every 273 feet rise, we may expect temperatures low enough to make "starting up" at least a matter of much difficulty, probably necessitating a hydrogen gas supply. It may be of interest to add details of two of the supposed highest aeroplane records. Hawker in 1916 attained a height of 24,000 feet. In 1914 the German Lieut. Oelrich attained a height of 25,750 feet. This was officially announced, but never ratified by the International Aeronautic Federation. It is, however, generally accepted as approximately correct. From the above considerations it would seem that the cost of evolving an efficient machine capable of being operated from a high altitude station, for the purpose of reconnaissance in the Himalayas, is beyond the limits of the funds of any privately organized expedition, but the actual possibility of eventually evolving a machine capable of achieving all the lecturer has indicated is not disputed.

Sir THOMAS HOLDICH: Dr. Kellas must know the Himalaya as well as I do, but possibly he has not experienced some of the difficulties that I have in dealing with atmospheric effects while surveying. The days when you can depend on seeing anything, particularly in the higher Himalaya, are very few indeed. It would be quite impossible for any man, starting in an aeroplane for a reconnaissance to take photographs, to say whether he would be able to see his way home. If Dr. Kellas confines his proposal to crossing the Himalaya, I do not think that is by any means impossible. But he would have to choose his route at the eastern end, passing over the Chumbi valley, following much the same route as our troops when they went to Lhasa. But what would he reach? Only Tibet. No doubt there is plenty of flat ground in

Tibet where he could land, and where, owing possibly to the general absence of snow, he could get off again. But the only reconnaissance of any use would be to make a start from one of the stations near the southern foot of the hills, and by a rapid flight into the Himalaya in an aeroplane fitted with photographic apparatus, particularly in the direction of Nepal, one might really get valuable results, though only a rapid reconnaissance. The airman would have to make a start early and be back by night. There would be no great altitude involved ; he would be able to see a great deal of country which we have never been able yet to see, and of which probably for many years we shall not be able to get anything like a reasonably good map, on account of political difficulties.

Captain SWINTON, R.E.: There are one or two points not touched upon, especially the very great difficulty of finding any pilot who could fly a machine in the wind currents that must certainly exist at those altitudes. I came across a case recently of an American pilot who had been flying the mountains in Mexico. On one occasion he came rather suddenly to a valley over a ridge in the bright sunlight, and he found himself, as he said, in a kind of inverted waterfall of hot air, which raised him several hundred feet and turned him upside down, to finish in the crater of an extinct volcano ; but fortunately he managed to make a landing the right way up. I should think that kind of thing might be expected in the Himalaya. A margin of 1000 feet between the machine and the mountains underneath would be rather small, and one would have a very considerable chance of getting into a bump or hole and having a crash before one could recover. No existing machine will go to 30,000 feet, and it seems to me there is not sufficient margin between the mountains and the upper limit of practical flying of to-day. Until we have a special form of aeroplane, we can hardly hope to negotiate successfully these frightfully mountainous countries, except as an exhibition flight or one of very great urgency.

Major G. I. TAYLOR, R.F.C. : I should like to say a little about the technical side of flying at these heights. In the first place, I do not think that there would be any great difficulty in the navigation. Admiral Mark Kerr said that it was impossible to tell in flying at great heights in which direction you are going. This is more true at sea than it is over land, because there is no fixed point at sea to use in estimating one's speed. I think it is perfectly possible to make navigating instruments which will enable you to determine your position to within 6 miles.

Admiral MARK KERR: I was referring to flying in the clouds.

Major TAYLOR: Even over the clouds I think it would be possible. The other question is that of landing. At the end of 1915 we experimented at Farnborough with a machine fitted with the skids referred to by Major Lees, and found it perfectly possible to rise and land on snow with them. I think if machines are fitted with skids it should be quite possible to land on snow without knowing beforehand whether it is hard or soft. But the real difficulty, to my mind, in landing on snow which you do not know, is that it is impossible to tell at what angle the snow is lying. Every one who has done any ski-ing knows that one cannot tell by looking at snow from above how nearly flat it is. One would be almost certain to crash an aeroplane in landing on a slope, if one could form no idea how the ground sloped till one touched it.

As to distance, to get up 20,000 feet one would have to fly a horizontal distance of about 100 miles anyhow, and machines can now be made which will fly 200 or 300 miles at that height. I do not really see any reason why one should not be able to make a survey starting from a distant low-level station, provided one cares to fly within 1000 feet of the mountains. That seems to me to be much the best plan. I do not believe it would be possible to land at those heights, because the photographs we have seen shown this evening do not, as far as I could judge, exhibit snow-slopes flat enough to land on; and besides, the landing speed at those heights would be more than $1\frac{1}{2}$ times as great as it is near the surface. But, technically speaking, I see no insuperable difficulty in flying at those heights and making a photographic survey.

Mr. FRESHFIELD: May I point out that when this scheme was first discussed with General Rawling, the suggestion rather was that an aeroplane should fly up to the flat country north of Everest, and having a good base there should be used in exploring, and to a certain extent, in a rough way, mapping the Everest group. There was no suggestion of these attempts at peaks, or anything of that kind. Something of that sort would be the way to first make attempts, and it might be worth while, after what we have heard, if a mountaineering party cared to do it, to back themselves up to that extent by aircraft.

Lieut. GRANT (Admiralty Meteorological Service): From the climatic standpoint the problem is interesting and complex. It is not difficult to fly over mountainous ranges at a great height, where the winds are practically horizontal. But experience, both in this country and in the Adriatic, etc., shows that in alighting in a mountainous country danger always arises, partly from eddies due to cross winds blowing along the valleys and partly from vertical currents. Such currents are rarely encountered except in mountainous regions, and the present type of machine is apt to lose its stability when it meets them. In snow-covered mountains also considerable katabatic winds are formed (especially on clear nights) through the chilled air pouring down into the valleys. Such storms commence abruptly and are of considerable violence. (In the Adriatic a corresponding type of conditions is known as "the Bora.") They have little or no relation to the barometric pressures. Under such conditions the present type of machine is apt to lose its stability. While every precaution should be taken, in the event of the proposal being proceeded with, to render the first attempt successful, no amount of critical discouragement should be allowed to lead to the abandonment of the enterprise.

The CHAIRMAN: I never remember a meeting of the Royal Geographical Society at which the project of a proposed expedition was received with a more unanimous negative on the part of those best competent to judge, except on the occasion when Dr. Fridtjof Nansen put before us the project of drifting across the Arctic Ocean in the *Fram*. I hope that will be a happy augury of the suggestion that Dr. Kellas has made. As to landing airships or aeroplanes on high mountain plains: I was told in the year 1913, and did not believe a word of it, that the main object of a German meteorological expedition, which had been camped for several years on the plains at the base of the higher slope on the peak of Teneriffe, was to establish a base for aircraft in the event of a war with this country, in order that they might harass the converging traffic from South Africa and South America round the Canary Islands. I was told that by a Spaniard in an official position. He was quite serious in the matter. I did not believe it then, but I am inclined to believe it now. That also, I think, is an indication that it may not be impracticable to land aeroplanes and get off again from high mountain regions. I will ask Dr. Kellas to reply.

Dr. A. M. KELLAS: I have been greatly interested in what has been said by the various speakers, but some of the criticisms have been under a misapprehension. The plan, as outlined, was to fly over the mountains or through the gorges, and carry out survey work from the north side of the main range, where the summer weather is comparatively good. With regard to the landing in snow, that was something extra, and was primarily in connection with experiments to protect the airman, who might be forced by engine trouble to land in awkward positions. Those who have read the paper will remember that what was stated—I am afraid I did not emphasize the point sufficiently—was that the use of aircraft would be for crossing the range, and bringing supplies, and in doing as much survey work as possible. As I pointed out, I was quite incompetent to deal with the matter from the aeronautical point of view, and I have been greatly interested in what I have learned regarding the difficulties of landing in snow at a high altitude, and starting again. But these are problems which will be worked out in part, I trust: the science of aeronautics is in its infancy. If it is possible to land at 15,000 or 20,000 feet and start again after a reasonable race, I do not see that the difficulties are insuperable.

# THE SOUTH-EAST FACE OF MOUNT KENYA

Captain G. St. J. Orde Brown, R.A.

SUCH exploration as has already been done upon Mount Kenya appears to have been largely confined to the northern and western aspect of the mountain. Mackinder and Gregory both attacked it from those sides, while the more recent Roosevelt expedition also largely neglected the south-east slope. The following notes are made without claim to scientific value, but in hope that they may be of use to subsequent explorers wishing to investigate the least-known side of this very interesting mountain.

The characteristics of the south-east aspect may be summed up as follows: A network of rivers spreads from the mountain like the sticks of a fan, all eventually finding their way into the Tana River. The gorges in which these rivers run are all far deeper and much rockier than those of the rivers on the other sides of the mountain; the country is decidedly more wooded, and numerous signs exist of an age recently passed when the forest was of a much greater extent. This very broken nature of the country naturally tends to perpetuate and accentuate peculiarities of all sorts, both of the inhabitants and of the flora and fauna. It may therefore fairly be claimed that the south-east side of the mountain is really the most interesting portion.

The expedition upon which I made the following notes was conducted from the eastern side of the mountain, while my general course was towards the peak, but with a trend which brought me eventually almost due south of the peak at the highest point which I reached. It must be explained that the local natives, although they do not live at a greater height than 6000 feet, frequent the forest up to 10,000 feet, or even more, native tracks being found fairly well kept at an even greater height. These are used occasionally as short cuts by men wishing to cross spurs