AIR PHOTOGRAPHY IN GEOGRAPHICAL
EXPLORATION AND IN TOPOGRAPHICAL
AND GEOLOGICAL
SURVEYING.

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ABSTRACT. Air photography is of great value in reconnaissance sur-
vays and geographical explorations of large areas. The camera records
geomorphological features, which give clues to the underlying geological
structures, and thus facilitates the rendition of both in cartographic
representation.

The value of air photographs in this respect is exemplified by those
taken during the rio Branco-Urarioeua-Parima expedition 1924-25. These
disclose that the serra Parima is a maturely dissected dome, elliptical in
shape, which trends N.N.W. Its longitudinal axis is more than a hun-
dred miles in length and its transverse axis over 60 miles wide. The
central core of crystalline rocks has an elevation of more than 4500 ft.
above the surrounding plain. Concentric to the central mass are monoclinal
ridges or rimming hogbacks which, on the eastern flank, are of sandstone.

The inferences as to topography and structure of the region as a whole
that could be gained from river craft, the only prior mode of access, are
wholly different from those which result from the true perspective aloft.
For the main river artery, the Parima, breaches the eroded infaces of the
narrow hogback ridges, and cuts formidable gorges where it crosses the rim-
ing sandstone ramparts at Tokixima and Kolaihia. Yet, as the air photo-
graphs record, the true character of the region is that of a broad plateau.
Other major errors of deduction that would result from exploration via
the waterways are shown by the aerial method.

THE full exploration of an unknown or little known region
is attained only when undertaken in conjunction with sur-
vying in order to secure maps that will give an essential
geographical description of the region. Where the construc-
tion of such maps is mainly concerned with mathematical prin-
ciples carried out by topographers and executed by cartog-
raphers, professional skill counts more than scientific research,
and the laying down of the observations has greater significance
than does interpretation. The usual topographer considers
his work done as soon as he has recorded the objects of his
survey. In like manner the cartographer feels he has com-
pleted his objective when he has inscribed on a map the obser-
vations of the topographer. Such a map may fail to give an
accurate and intelligible representation of surface features not-
withstanding the correctness of their geographical positions.

If the recorded surface features are to have an explanatory
value as well as a narrowly geographical one, the topographer should have in addition to his professional skill some knowledge of the geological processes with which physical geography is concerned. He should also have the ability to interpret processes modifying the earth’s crust which are evidenced by its geomorphological features. Such preparation applies also to the cartographer, for no matter how expert he may be in the technique of expression, the explanatory value of his work is considerably enhanced if he has some knowledge of the cause which has produced the effect that he seeks to represent.

The value of air reconnaissance in accurate geographical survey becomes immediately apparent. Hence the indispensable rôle played by air photography and radio-telegraphy as integral parts of such survey mark the new era in exploration that followed the First World War. Each in its respective field expedites the work to an extraordinary degree. Radio-telegraphy fixes longitudes through the utilization of time signals in determining geographical positions and the control points of maps by astronomical methods. Air photography, as a complementary factor of radio-telegraphy, affords opportunity for the construction of maps as scientifically accurate in their interpretative and explanatory expressions of surface features as they are mathematically exact in their geographical positions.

Exemplification of the striking contrast between the effectiveness of exploration conducted in the previously conventional manner and that enjoying the benefits of the new techniques is found in expeditions under my direction in tropical South America. Unlike those which I had earlier conducted, the expedition of 1924-1925 to rio Branco-Uraricura-Parima in Brazilian Guayana was served by aerial photography and radio-telegraphy. The following pages emphasize some of the advantages that resulted from the employment of those methods.1

The procedure as exemplified on the Parima river depended on hydroplane2 reconnaissance for enormously simplifying and

1 A general account of the expedition was presented by me before the Royal Geographical Society of London (Geog. Jour., 71, pp. 113-143; 209-223; 345-357, 1928). Reports on special parts of the expedition’s work appear in volumes 65-69, 74 and 76 of the same journal.

expediting the work of the ground party of the expedition. The latter proceeded by canoes obtained from the Makú Indians whose mallowa is situated on the left bank of the river just above Tokixima gorge. The crews, picked from these same Indians, consisted of those most familiar with the details of the

Fig. 1. Map of a section of the rio Negro just above the Bocaçu where the river is almost 20 miles wide by reason of existing physical conditions impossible of detailed survey by ordinary ground methods.

region. Because the aerial reconnaissance indicated just where the canoes could effectively proceed, the ground party was able to concern itself largely with physical, biological and ethnic investigations; but one of its important functions was the establishing of precise ground control and making this manifest by appropriate markers to be recorded in the air photography.

The framework of the map evolved on this expedition consisted of astronomically fixed positions that controlled the boat
compass traverses made on all rivers navigated. Where possible, air photographs filled in the detail. Only certain sections of the rivers were photographed,—about 200 oblique photographs of the rio Negro; 60 vertical views of the bifurcation of the Uraricuera with a camera of 12-inch focus, from a height of 6,000 ft.; 15 oblique views of the Caracaraya Falls of the rio Branco; a number of vertical photographs of the rio Branco from Boa Vista to the junction of the Uraricuera and the Takatu, and also of the latter river.
Perhaps the most significant feature of these air photographs is their wealth of detail and the opportunity thus given the cartographer to construct an accurate and elaborate map of the maze of water courses that never could have been surveyed by ordinary ground methods. This is demonstrated most forcibly when the survey is compared with the one made by the author in 1917 of the same stretch of the rio Negro between Manaos and the junction with the rio Branco. The resulting map of the 1917 survey is empty and vague indeed in comparison with the elaborate and accurate detail of the map made from the 1924-25 survey. See Text figures 1, 2, and Plate 1-A.

Rivers of tropical South America are of three types, viz., black-water rivers, white-water rivers, and those poor in sediment, or lacking it entirely but having no characteristic color. Black-water rivers, whose golden brown or mirror-black color characterizes them, derive their sable appearance from a stain or dye of iron compounds acted upon by humus acids. Where the action of the humus acids is neutralized by a large amount of calcium carbonate and abundant decomposition products of the feldspars of gneisses and schists are present, a condition of finely divided hydrous, aluminous silicates ensues. Running water carries these in suspension, and they in turn impart to the water the turbid color and erosive quality that characterize so-called white-water streams. When the component substances that form a black-water river and a white-water river neutralize each other, there prevails a type of river whose water is thin and colorless, with little or no sediment. The rio Negro represents the first type; the Amazons-Solimões and rio Branco are of the second type; while most of the northern affluents of the Amazons to the east of the rio Negro, and the Tapajos and Xingú of the southern affluents, are examples of the third type. Plate 1-B is an air photograph taken from a height of 2500 ft., showing the meeting of the black waters of the rio Negro with the so-called white waters of the Amazons-Solimões which are of a dirty, light brown, turbid appearance. The line of demarcation is maintained for a distance of 12 miles or more below the confluence, the black water from the Negro clearly discernible along the left bank extending for some way into the stream.

Each type of river has its characteristic vegetation. With white-water rivers, the terms igapó, varzea or vargem, and terra
Fig. 1A—Air photograph of the rio Negro in the section of the river as represented in Fig. 1 and Fig. 2.

Fig. 1B—The line of demarcation between the black water of the rio Negro and the so-called white waters of the Amazonas—Solimões.
Fig. 2A—Scene on the lower Uraricuera, where the height of the trees, as well as the density of vegetation, would indicate Amazonian forest, but air photography discloses a very different picture of the landscape, in Pl. 2-B, a little distance from the river.

Fig. 2B—Here is revealed a broken plain of "old age" stage with erosion remnants of granite and gneissic monadnocks that rise considerably above the general level of the region. The elevation of the plain is but little more than 200 feet above sea level.
Fig. 3A—The middle portion of the Uraricuera is broken by many islands and rapids. Conditions are such as to preclude all possibility of carrying out a ground survey of any sort, and it is under such conditions as these that the employment of air photography for filling in the details is essential and imperative.

Fig. 3B—Assahy caxocira looking west, showing the braided pattern of the river. In the left background may be discerned the serra Parima more than 70 miles away, a dome which rises 4500 feet above the surrounding plain.
Fig. 4A—Tokixima gorge where the rio Parima breaks through the sandstone rampart of serra Uaimiti. It was in flying above this gorge that Hinton and Stevens narrowly escaped destruction, compelled to follow the curves of this narrow steeply-walled canyon, owing to steady loss of elevation by the plane through the boiling-point condition of the engine by reason of the excessive heat of the region.

Fig. 4B—Kolaihia gorge, looking southwest from the left foreground may be plainly discerned the right-facing rimming hogback of the Domanahuika-Maxauaka, resting unconformably on the granites and schists of the core of the serra Parima.
firme are so generally used by the inhabitants of the Amazons in connection with riparian description that one should have a clear understanding of their meanings. On the Amazons and its tributaries, the inhabitants distinguish the marginal land as igapó, never more than 15 ft. above low water; varzea or vargem is the land which by successive deposits has risen above the ordinary level of the river and is submerged at high water; terra firme is ground which the river never overflows, composed of the yellow-red clay, topped with thick forests, that is common to the entire river valley.³

A practical advantage of air photography in river surveys such as the Uraricuera is graphically shown in Plate 2-A and 2-B respectively. Plate 2-A shows a canoe of the Batalão type equipped with an outboard motor on the lower Uraricuera, passing a portion of the river where the riparian vegetation completely obscures the true character of the region from the observers in the canoe. It would naturally be inferred that the tropical luxuriance of the jungle-like growth along the river bank was a fringe of Amazonian forest. But air photography discloses a very different picture of the landscape. Immediately behind the aboreal screen, as is revealed in Plate 2-B, is a broken plain of old-age undulating topography with erosion remnants of granitic and gneissic monadnocks rising considerably above the general level of the region.

Plate 3-A vividly illustrates the usefulness of air photography where conditions preclude all possibility of carrying out a ground survey by reason of the labyrinthian character of the channels that mark the bifurcating of the Uraricuera river at the western end of Maraca island.⁴ This network of intricate channels, however, is not confined to the western end of Maraca island. It extends from Kulekulema to the eastern end of the island through the furo Maraca, a stretch of 100 miles. There exist other stretches of channel-filled aits and eyots at the caxoeiras of Assahy, Kusali and Takari, the river wandering braided-fashion apparently regardless of the underground structure (see Plate 3-B). These, in connection with

³ One of the best and most comprehensive articles on the subject is entitled Mattas e-madeiras-amazonicas, Dr. J. Huber, Boletin do Museu Goeldi (Museu Paraense) de Historia Natural e Ethnographia, vol. 6, 1909, Para, Brazil.

⁴ The map showing detail of the entire region covered by the expedition of 1924-25 will be found in the Geographical Journal, vol. 71, following p. 416, 1928.
the frequent rapids caused by the beveled edges of the more resistant formations, varying from granites to schists and gneisses, the undulatory topography and comparatively low height above sea level, are indicative of old age, further confirmed by the character of the open country on the lower Uraricuera with its not infrequent erosion remnants or monadnocks as shown in Plate 2-B.

As one goes up stream from Assahy caxoeira, hills are more frequent and prominent. Two days' travel above Assahy caxoeira is Takari caxoeira, and a few hours above, Malipayapong caxoeira blocks the way where the river changes from southing to easting. Fifteen miles above Malipayapong is caxoeira Marutani. From there, about the same distance to the north, is the table-topped mass of white standstone—the serra Marutani—toward the southern aspect of which the big loop made by the Uraricuera is extended. Twenty miles up stream from the westerly beginning of the loop on the left bank, parallelopipedons of red sandstone make their appearance and a few miles on is the Uaimiti or Uidxa caxoeira. This is marked by a long, tabular mass of sandstone on the right bank and high rounded hills on the left, the effect being that of a portal through which the river passes. From there to Tokixima where the Parima river rushes boiling and seething through a deep gorge (Plate 4-A) for nearly five miles to become the Uraricuera, the river is narrow and is flanked, fortress fashion, on the right or south bank by the serra Uaimiti. The grimness of the pile is softened somewhat by the verdure with which Nature has covered it, though, where the scarred reddish-brown walls are exposed, the boldness of the pointing and bedding and size of the blocks are apparent. The cliffs and precipices, ledges and galleries, rents and ravines—evidence of the demolition through erosion over epochal time—are characteristic of the sandstone found over extensive regions in the Colombian Caqueta, and the Venezuelan and Brazilian Guayanas.

There is a four-hour stretch of quiet water by canoe travel from Tokixima to Kolaihia gorge (Plate 4-B), the river flowing due north in the longitudinal valley between the inner and outer rimming hogbacks of Damanahuika-Maxauaka (Kolaihia) and Uaimiti-Luimeuiga (Tokixima) respectively. The river races, boiling and swirling, between the sandstone cliffs of three-mile long, narrow and tortuous Kolaihia gorge. Toward the entrance of the gorge, schists appear upon which
the sandstone rests unconformably, but from the gorge to the source of the Parima, 40 miles as the crow flies, no sandstone is encountered. Three miles above Kolaihia gorge, the Auari comes in from the west, a stream that may at some time in the past have been the extreme upper part of the present Uraricuera. Although there are stretches of quiet water in the inner valley of the Parima river as one ascends from the gorge to its source, similar to those which exist in the outer concentric valley between Tokixima and Kolaihia, nevertheless, the river is much broken by rapids. During the seven days consumed in reaching the source from Kolaihia, there were only two occasions of extremely short duration when anything resembling a mountain range could be discerned to the west or west-south-west. Stevens and Hinton, however, ascending the river by hydroplane, could constantly observe the central core of the serra Parima dome to the west and the monoclinal ridges on the east. The ledges of the rapids-broken bed of the Parima river invariably trend northwesterly and are marked by steep hills across whose longitudinal axes the river cuts its way.

For more than a century the probable geographical location of the source of the Orinoco river has been a much mooted subject. Richard Spruce, the English naturalist, who was associated with Alfred Russel Wallace and Henry Walter Bates (renowned names in the annals of geographical exploration of tropical South America of the middle 19th century), writing from San Carlos, rio Negro, in June 1853 to Sir Wm. Hooker in London, quoted one Don Diego Pina concerning the upper Orinoco and its source. Pina held that the real sources of the Orinoco are very much to the eastward of where Humboldt, in his Aspects of Nature, presumed the source to be. It seems clear that they are at least considerably to the east of the sources of the rio Branco, or, in other words, that the system of the rio Branco overlaps that of the Orinoco—Spruce adds, sententiously, that this is a circumstance not without parallel. Pina, an old man at the time Spruce wrote, had long been regarded as the one who knew most concerning the country between the Casiquiare and the sources of the Orinoco; he had been Comisario of San Carlos, rio Negro, when Schomburgk had passed that way and he remembered Humboldt.

Chaffanjon, a Frenchman, leaving Esmeralda in December, 1886, with a crew of natives, passed the raudal de los Guaharibos and after two more days of very slow going, because of
rapids, arrived at another raudal, where most of the crew remained. Chaffanjon with two natives, in a small canoe, continued the ascent for four days more to a point where he claimed the river took origin.⁵

One of these two natives who accompanied Chaffanjon, named Pedro Caripoco, was residing at Esmeralda in January, 1920 and was the eldest member of my 1919-20 expedition in an attempt to reach the source of the Orinoco by ascending that river. Chaffanjon's claims and Caripoco's story do not strictly agree. Caripoco was positive that they did not reach the source of the Orinoco, but that when they turned back, the Orinoco was still a narrow, deep caño with no sign of coming to an end. The old Indian's mentality was excellent, his memory acute for detail and for the past: his veracity was in keeping with his other admirable qualities.

Shortly before we reached the end of canoe navigation on the Parima river, the remains of a bridge were noted similar in construction and condition to the Guaharibo bridge said to have been built by the Indians on the Orinoco. Here Parima river was 112 feet wide and there were 75 feet of the bridge standing, the piles strongly lashed to the trusses with cipo. At either bank vines had been rigged at quite a height from the stouter trees to give added strength to the structure.

During 1943, Major Art Williams of the Army Air Forces made several air reconnaissance flights over the serra Parima region during which air photographs were obtained of the source and course of the extreme upper Orinoco, which he claims has its origin south and a little to the east of the source of the rio Parima. If this is correct, and it may well be, the source of the Orinoco is at least 70 miles east of the raudal de los Guaharibos. Though Major Williams had no way of fixing the position, he has, with compass and camera, by air survey and air photography, revealed the truth of a fact whose prelude of doubt and obscurity has continued for more than one hundred and fifty years.


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