THE ESTIMATION OF GROUND CONDITIONS FROM AERIAL PHOTOGRAPHIC INTERPRETATION OF VEGETATION TYPES

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THE engineer, forester or geologist who is contemplating ground reconnaissance of an area with which he is unfamiliar can profit greatly by detailed advance information as to the ease with which various parts of the area can be traversed afoot and with mechanized equipment. To the military commander planning the seizure of enemy territory, such advance information is of the utmost importance. In peacetime aerial photos may provide one of the quickest and least expensive sources of this information. During war time they frequently provide the only source.

In estimating ground conditions the photo interpreter can make valuable use of his knowledge of the ecological site characteristically occupied by each species of vegetation identifiable on aerial photos. There are numerous familiar examples of the site preferences of vegetation. Willows prefer stream banks, sagebrush and cactus indicate very dry sites, the bald cypress thrives only in swampland. In the tropical Pacific area where, during World War II, aerial photo interpreters were called upon to estimate ground conditions affecting military operations, many species of vegetation show similarly specific site requirements. Mangrove trees indicate muddy salt water swamps, casuarina trees prefer firm sandy beaches, and sago palms occupy fresh water swamps.

In some cases a simple and plausible explanation for this site specificity of plants is readily found. Thus, willow trees are said to require large amounts of soil moisture because, under atmospheric conditions favoring excessive loss of water vapor from leaves, the stomates (pores) in willow leaves, unlike those in most leaves, do not automatically constrict. Unrestricted transpiration is the result.

In other cases more involved explanations are given. Mangrove trees are said to be confined to salty water because fresh water is not sufficiently buoyant. This factor is critical at the time when the mangrove seedling falls from the viviparous parent tree into the salty water. The seedling is a foot or more in length with a heavy primary root at the lower end and a delicate leaf bud at the upper end. If the water is sufficiently salty and buoyant the seedling floats with its long axis in a horizontal position until it becomes stranded on a mud bar whereupon it promptly sends out roots and becomes firmly established. However, if the seedling drifts into fresh water the reduced buoyancy permits the heavy root end to sink, so that the seedling floats in an upright position with the result that the delicate leaf bud is lifted free of the water and is scorched by the sun. A large percentage of the mangrove seedlings are so heavy that they sink to the bottom in fresh water. This is equally efficacious in limiting mangroves to salt water areas.

Such explanations as the foregoing are often helpful to the photo interpreter in determining the plausibility of his interpretation of plant-site relationships on aerial photos.

Figure 1 shows an aerial photo taken during World War II of enemy-held territory in the Solomon Islands. Let us assume that the aerial photographic interpreter has been asked to study this area in an effort to determine its suita-

FIG. 1. Vertical aerial photograph of portion of Bougainville Island, Solomon Islands. For explanation of annotations, see text.

bility for a contemplated amphibious landing. From observation of the pointed shadows of trees at A (compare with the rounded shadows of trees along the river near B) the interpreter recognizes these to be casuarina trees, indicative of a firm sandy beach, ideal for the landing of mechanized equipment (see Figures 2a and 2b). The light tone, feathery texture, and uniform height of vegetation at B on Figure 1 enable the photo interpreter to identify it as nipa palms, which indicate muddy brackish swamps. As shown in Figure 3, these swamps constitute extremely difficult barriers to movement of troops and supplies. A break in the jungle canopy at C on Figure 1 permits light to shine directly on the forest floor, thus supporting a dense tangle of undergrowth at the periphery of the clearing as shown in Figure 4. The completeness of the overhead crown canopy formed by jungle trees at D on Figure 1 prevents sufficient light from striking the forest floor to support an appreciable amount of undergrowth. Accordingly, conditions at D are estimated by the photo interpreter to be essentially as shown in Figure 5. The uniformly dull grey tone and "velvety" texture of vegetation at E on Figure 1 identify it as "pit-pit grass" (wild sugarcane) which averages 6 to 8 feet in height along stream banks (see Figures 6a and 6b). Troops attempting to traverse such an area find orientation difficult since the height of the cane makes it impossible for them to see for more than a

FIG. 2a. Sandy beach analogous to area A, Figure 1. Morning glory vines and pandanus trees in foreground; casuarina trees silhouetted in background.

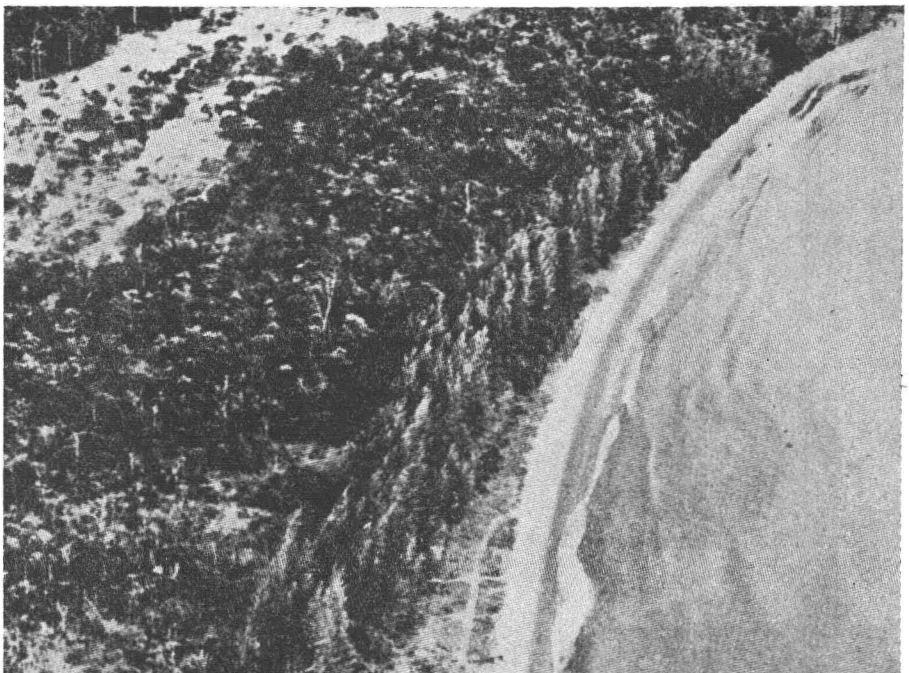

FIG. 2b. Aerial oblique photograph of area analogous to area A, Figure 1, showing sandy beach fringed by casuarina trees.

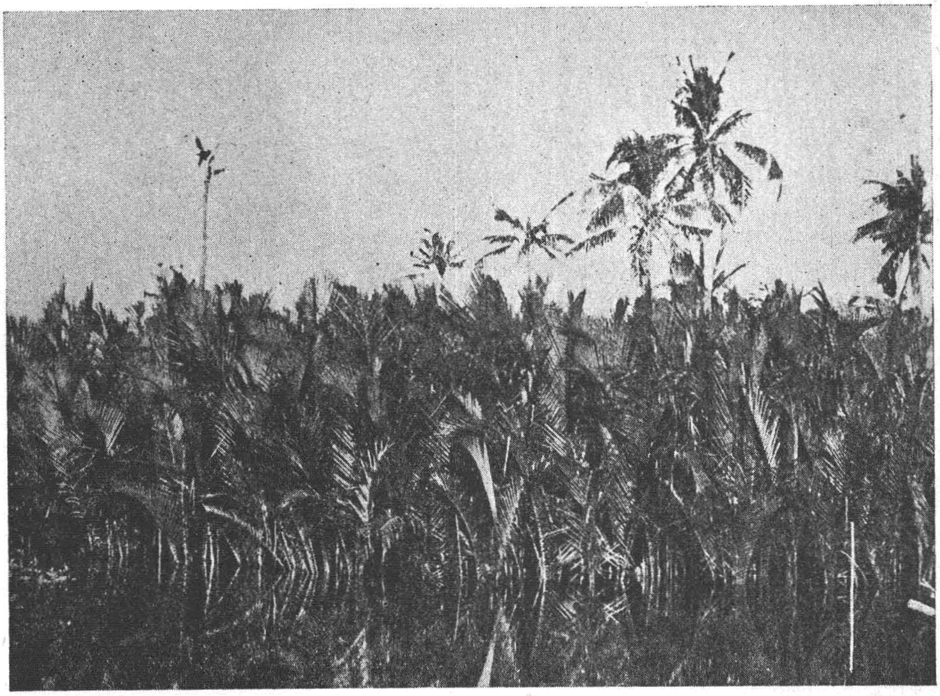

FIG. 3. Nipa palm swamp similar to that appearing at area B, Figure 1.

FIG. 4. Clearing fringed by secondary growth and rainforest. Comparable to conditions at area C, Figure 1.

few feet. Other factors adding to the difficulty of traversing wild cane afoot include the density of its growth, the sogginess of the ground, and the stagnant, hot, humid, dusty, pollen-filled atmosphere which engulfs troops in such an area.

The photo interpreter who is familiar with tropical terrain readily recognizes the meander scar at F as indicative of the presence of an oxbow lake covered by swamp forest vegetation of the type shown in Figure 7. Since swamp forest is normally confined to fresh water, area F is probably above the high tide range of the ocean. Area G on the other hand, is interpreted as being subject to flooding at high tide since nipa palms, easily recognized in this area, are normally confined to brackish water.

FIG. 5. Rainforest with very little undergrowth.
Analogous to area D, Figure 1.

The deflection of the river mouth in the direction of the left edge of Figure 1 indicates a long-shore ocean current from right to left which should be considered in planning an amphibious landing. The moderate mobility of the beach material evidenced by the spit to the right of the river mouth tends to confirm the interpretation, based on identification of casuarina trees at A, that the beach is composed of sand, rather than of mud or gravel.

In summary, the photographic interpreter might state with a high degree of certainty, on the basis of the foregoing analysis, that troops and mechanized equipment could be easily landed along the beach at A, but that they would be literally "swamped" with difficulties when they attempted to push inland.[1]

It would be of value to know if the enemy, who can explore this area thoroughly on the ground, has reached the same ultimate conclusion as the photo interpreter, namely, that this is a relatively poor area for an amphibious landing. If a study of the aerial photos shows, as in this case, that certain nearby areas of the coastline are defended, whereas the area in question is not, such a confirmation of the photo interpreter's conclusion is indicated.

Although the factors of tone, texture, shadow, height, etc. were largely used in identifying vegetation types in Figure 1, and from this, site conditions were estimated, the reverse process is sometimes used. Thus if the photo interpreter

[1] This analysis has purposely omitted reference to such important aspects of the photo interpreter's problem as determinations of enemy defenses, underwater depths over the fringing coral reef, etc., since they are considered to be outside the province of this article.

FIG. 6a. Wild sugar cane (Pit-pit grass) growing along river bank as shown at area E, Figure 1.

found it difficult to determine whether a certain light-toned vegetation with palm-frond leaves were nipa palms or coconut palms, but he could see water standing around the base of the palms in numerous places as at area G in Figure 1, knowledge of the site preference of each type of palm would enable him to eliminate coconut palms with a fair degree of certainty.

This may cause the reader to wonder if the photo interpreter has really accomplished anything by such a process, because his ultimate objective was to describe the site, knowing the vegetation, and yet in this last instance he could

FIG. 6b. Sugar cane, showing typical height and density of the growth.

not be sure of the vegetation until he had identified the site. However, a more careful analysis shows that the interpreter first eliminated all but 2 types of vegetation independently of the site and then, by noting the swampiness of the site, made the final elimination. He is now able to estimate conditions at the site in much greater detail than can actually be seen on the aerial photos for he knows intimately the ground conditions associated with a typical nipa palm swamp (Figure 3).

Similar examples of the use of easily recognized site factors in vegetation identification appear in the following dichotomous key to the principle types of native tropical vegetation in the Pacific. The writer originally devised this key

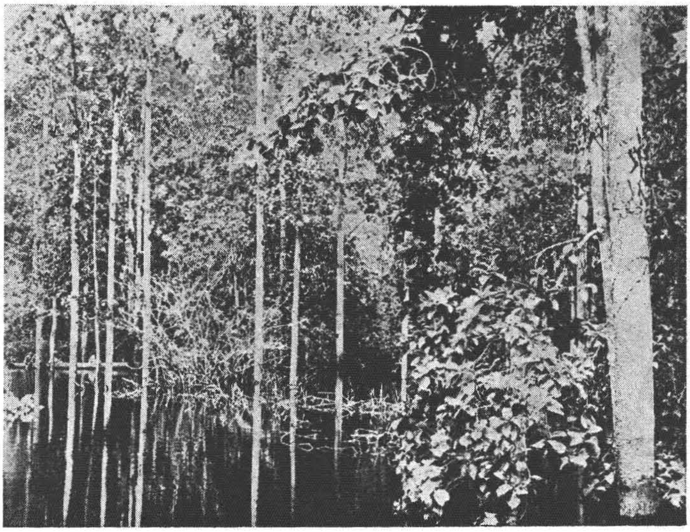

FIG. 7. Swamp forest similar to that indicated at area F, Figure 1.

as an aid in teaching vegetation recognition to photographic interpretation officer-students during World War II. Its workability is evidenced by the fact that after 2 or 3 hours of preliminary instruction, students were able, with the aid of the key, to identify vegetation types with an average accuracy of 80 per cent, working with photos of the type shown in Figure 1. Additional practice, of course, increased this accuracy appreciably.

The key is presented here to indicate which of the features recognizable on aerial photos have diagnostic value in vegetation identification, since the same principles are applicable to a similar problem in other localities.

To illustrate the use of the key let us assume, for example, that the light-toned vegetation fringing either side of the river at B on Figure 1 is to be classified. Reference to Part A of the key shows that the first decision to be made is whether or not the vegetation in question has palm-frond leaves. A study of the periphery of this vegetation reveals both individual fronds overhanging the water and individual shadows cast on the water by these fronds, though considerable detail is of course lost by photolithographic reproduction of the photo. Part A of the key indicates that on the basis of this interpretation, Part B of the key should next be consulted rather than Part D.

Part B offers several aids to further separation. That the vegetation in ques-

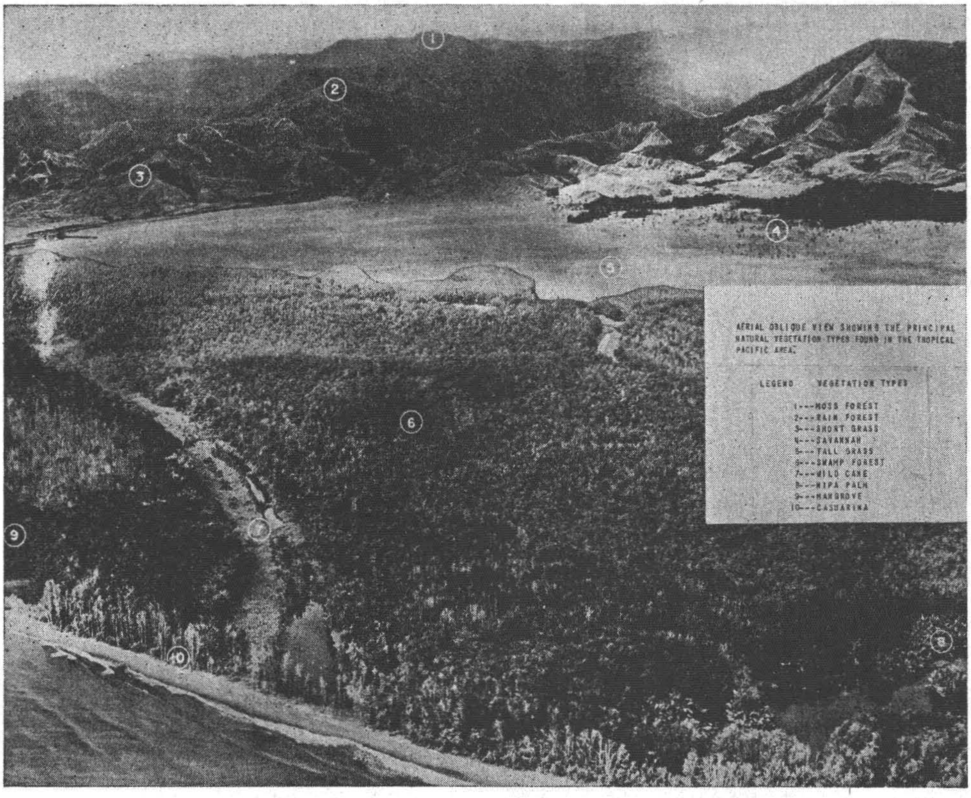

FIG. 8.

tion is only about one tenth as high as that at A on Figure 1 is indicated both by the relative lengths of the shadows and by stereoscopic height perception which the interpeter achieves by fusing this photo with the adjacent overlapping vertical photo of the run. Obviously, then (referring to the alternatives in the key), the vegetation at B in Figure 1 is less than 30 feet in height; otherwise the trees at A would have to be taller than any known to exist. But the conscientious interpreter continues further in Part B of the key and confirms the above conclusion by noting that the vegetation in question is in relatively pure stands and occupies a swampy site. The key therefore directs him to Part C where he finds that the vegetation in question fits the description of nipa palm in all respects.

The reader may find it both interesting and surprisingly simple to key out other vegetation types shown on Figure 1. Only characteristics which are ordinarily readily recognized on aerial photos have been used, but as in most dichotomous keys, if it is impossible at some point to decide which branch to follow, the procedure is to arbitrarily take one branch or the other. If the wrong branch has been chosen this soon becomes apparent by failure of subsequent descriptions to fit the vegetation in question. With as many diametrically opposed characteristics as appear for example, in Part C of this key, there is ordinarily little doubt as to whether the vegetation in question falls in one category or the other. Most of the vegetation types described in the key appear in the composite oblique photograph shown in Figure 8.

KEY FOR THE IDENTIFICATION OF VEGETATION TYPES IN THE TROPICAL PACIFIC AREA

A	Plants with palm-frond leaves	See B
A	Plants without palm-frond leaves.	See D
B	Trees up to 100 ft. in ht.; scattered rather than in pure stands; normally confined to well drained sites.	Coconut
B	Trees less than 30 ft. in ht.; in nearly pure stands; normally confined to swampy sites.	See C
C	Leaves light in tone; rarely in distinct rosettes; all plants in clump of uniform height (about 10 ft.); without distinct flower stalks. Usually grow in compact stands along stream banks near coast with roots submerged in brakish water.	Nipa
C	Leaves dark in tone; in distinct rosettes; plants in same clump usually of variable height (10–30 ft). Conspicuous white flower stalk frequently protrudes above center of rosette. Usually grows in rather open stands in areas subject to periodic flooding by fresh water.	Sago
D	Plants growing in swampy or poorly drained soil; subject to frequent flooding.	See E
D	Plants growing in well drained sites; rarely or never subject to flooding.	See G
E	Grass of uniformly grey tone and with "velvety" texture resembling sugar cane; usually confined to stream banks.	Wild Cane
E	Trees of variable tone and texture.	See F
F	Trees usually dark in tone, with uniform height of 20 to 40 feet; confined to muddy coastal fringes and stream banks inland to the limits of brackish water.	Mangrove
F	Trees of mottled tone and variable heights up to 150 feet; often bounded on the seaward side by mangrove and on the landward side by rainforest.	Swamp Forest
G	Grass of uniformly grey tone and very fine texture.	See H
G	Plants of mottled tone and coarse texture	See I
H	Grass from 4 to 12 feet high; on moist level sites.	Tall Grass
H	Grass from 1 to 4 feet high, on well drained rolling to steep terrain.	Short Grass
I	Bushes and trees (20 feet or less in height) densely entangled by vines; ordinarily confined to areas that have been cleared of jungle in recent years by man, fire, landslides, etc., and left to revert back to the jungle climax vegetation. Usually bounded by jungle hardwoods on at least one side.	Secondary Growth
I	Trees 50 feet or more in height.	See J
J	Trees resembling pine with narrow, pointed crown and long slender stem extending nearly to top of tree. These features frequently discernible from shadow cast on light-toned sandy beach to which tree is usually confined; crowns of trees have a light grey tone in aerial photos	Casuarina
J	Trees with broad, rounded crown and branching stem.	See K
K	Trees widely spaced, with grass-covered ground readily apparent between them; confined to dry areas.	Savannah
K	Trees densely spaced, with bushes and vines, instead of grass, constituting the understory; confined to humid areas.	See L
L	Trees normally confined in tropics to altitudes of 4,000 to 11,000 feet. Light in tone because of light reflected from dense growth of moss and lichen on branches and ground. Tallest trees usually less than 100 feet high.	Moss Forest
L	Trees ranging from sea level to an altitude of about 6,000 feet. Mottled in tone, being composed of many species of trees which almost invariably grow in mixed stands. Tallest trees 150 feet high or more.	See M
M	Dense undergrowth beneath trees; crown canopy of trees usually of variable height with frequent small openings where direct sunlight can strike ground. Common on steep slopes, along stream banks and at edge of clearings.	Rain Forest with Undergrowth
M	Very little undergrowth beneath trees; largest trees form almost continuous crown canopy which permits little or no direct sunlight to strike the forest floor.	Rain Forest

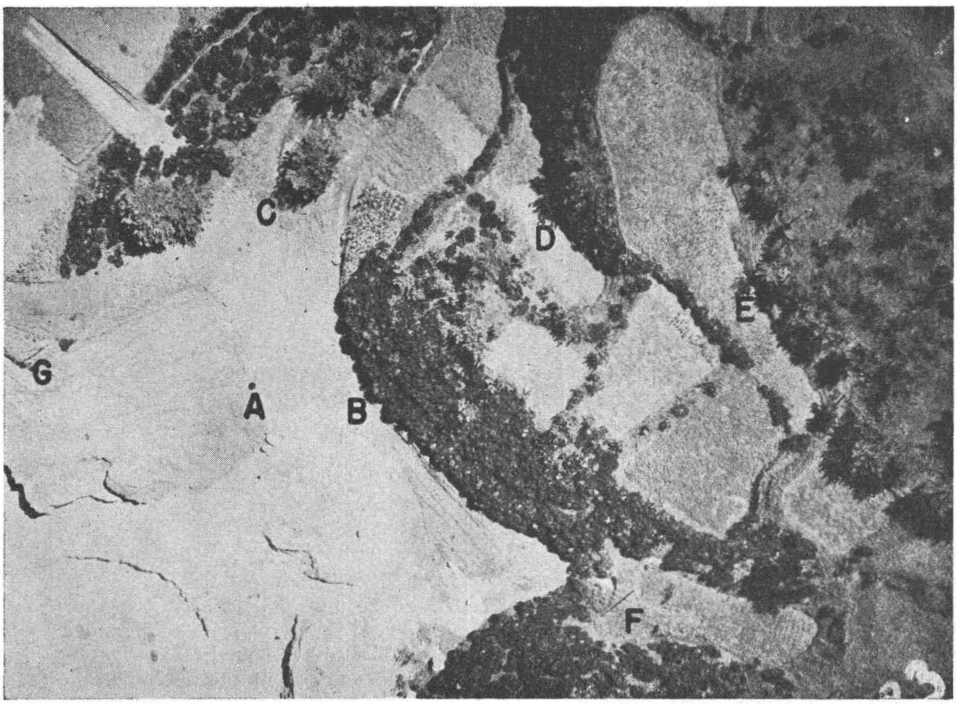

FIG. 9a. Vertical aerial photograph showing concentrations of cycads in limestone area at Okinawa. For explanation of annotations, see text.

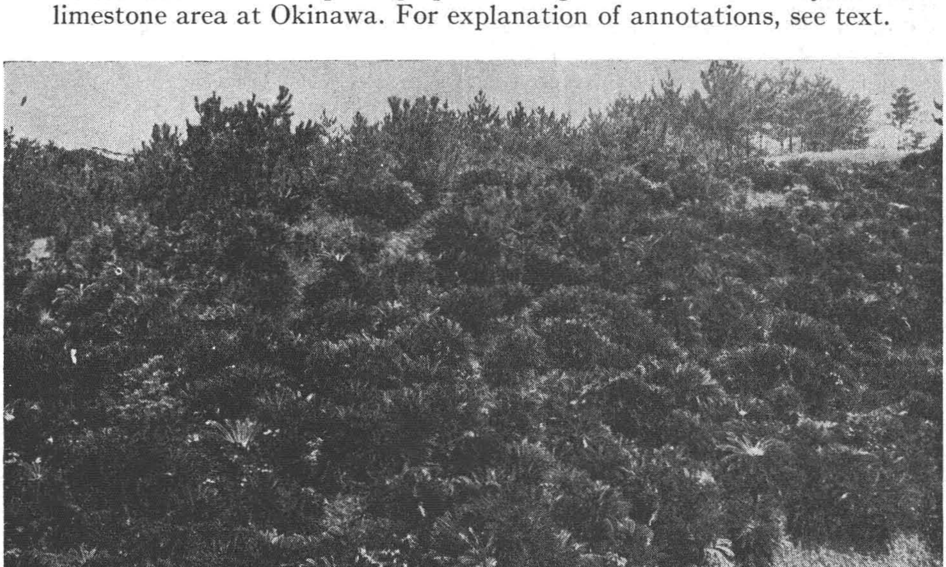

FIG. 9b. Photograph taken from point A, Figure 9a, looking toward point B. Cycads in foreground; pines in background.

Figure 9a is a vertical photograph taken by the writer at Okinawa to demonstrate the ease with which cycads may be recognized on aerial photographs from the very dark-toned rosette of leaves and the central white seed stalk. (Compare with Figure 9b which is a ground photograph taken from point A on Figure 9a looking toward point B). In the Ryukyus such dense stands of cycads indicate coral deposits at or near the surface of the earth. Ability to recognize such sites on aerial photos is of military importance since, as shown in the lower portion of Figure 9a, they are ideally suited to borrow-pit excavation of coral needed for surfacing roads and airfields.

Shadows on Figure 9a permit the experienced photographic interpreter to identify bamboo trees at C, pine trees at D and E, and telephone poles at F and G, with even the shadow of the wire discernible intermittently.

Estimates of ground conditions made on the basis of vegetation types can often be confirmed or elaborated upon from geological evidence discernible in the aerial photographs. For example, the fact that only dry-land crops were cultivated in a certain area of about 30 square miles on Okinawa indicated to the photo interpreter that despite the heavy rainfall valuable paddy crops could not be grown here, as they were in neighboring portions of the island. Whereas rivers and streams drained the neighboring areas at frequent intervals, it was noted that not one stream drained the area in question in nearly 10 miles of coastline.

From the standpoint of both plant ecology and geology it would appear that within the area in question a shallow and fertile layer of topsoil was underlain by a very porous substrate which reduced surface runoff to a minimum. That this substrate was probably calcareous in nature was evidenced on aerial photographs by occasional coral borrow pits being used by the enemy throughout the area.

Since a shallow covering of soil prevents coral from becoming case-hardened and difficult to work and at the same time minimizes the amount of digging necessary to expose the coral, this gently-sloping, well-drained area would appear to possess a happy combination of factors from the standpoint of airfield construction.

The concentration of airfields which the Allies eventually built in this area bear testimony to the correctness of the foregoing analysis.

A more detailed treatment of the applications of plant ecology and geology to problems confronting the aerial photographic interpreter will be found in a training manual entitled "Pacific Landforms and Vegetation" published by the U. S. Naval Photographic Intelligence Center, Washington, D. C.

RESOLVING POWER

THE Society has received a copy of *Phototopography*, prepared by the 648th Eng. Topo. Btn. (deactivated). It was presented by Charles A. Thielen, a member of the Society, and presents a very interesting picture of the field applications of Photogrammetry under AFPAC.

A new firm, specializing in photo-exploration, with emphasis on the search for oil, has been organized. It is Geophoto Services, Inc., 136 E. 20th St., Denver, Colorado. Laurence Brundall, a Vice-President, is a member of ASP.