The Use of Vegetation Analysis in the Photo Interpretation of Surface Material

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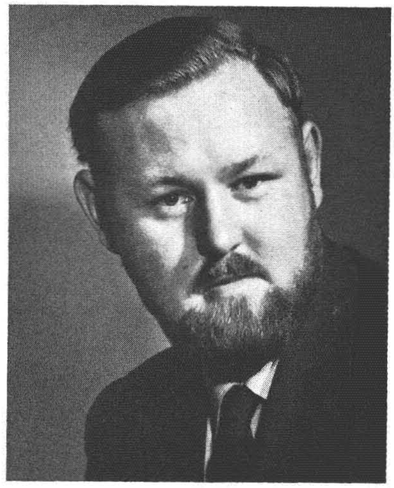
ABSTRACT: *A geographic approach to photo interpretive studies, stressing the interdependence of natural features, rather than their isolation, is postulated. As an example, the relationships between natural vegetation and surface materials observed during photo interpretation over a period of years are presented. For various types of surface material, in each of several major climatic zones, indicator species, and indicator associations of species are advanced. It is proposed that the recognition of this relationship can be used as a valuable criterion in the photo interpretation of surface material. While for the purpose of this paper the examples have been restricted to parts of Canada, it is suggested that the concept is valid in other areas, and may be used to advantage in surface material interpretation.*

DENSE vegetation creates a problem in many photo interpretation studies, particularly those directly concerned with soil analysis, route and site location, search for aggregate, and the numerous engineering projects associated with the nature of surface material.

A considerable number of such resource surveys have been completed by the Resource Engineering Department of Spartan Air Services Limited. It has been found that within the broad climatic classifications of forest types, the relationship of a number of forest species to their environment acts as a reliable indicator of surface material, drainage conditions and occasionally rock-type. This approach when used in conjunction with all possible evidence derived from the usual criteria of interpretation, allows a considerably more accurate analysis of surface material in these difficult areas than would otherwise be the case.

Such environmental relationships can be acceptably constant only in areas with similar climatic characteristics. Thus, in a large region, particularly one with a considerable north to south extent, such relationships must be considered separately for each climatic zone.

For the purpose of this short note, the relationships discussed will be those found in



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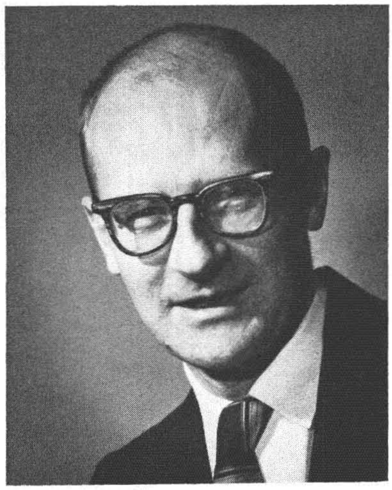
Canada east of Manitoba, excluding the Maritimes and Eastern Townships (Figure 1). Within this region three main climatic zones associated with typical forest associations can be recognized. (1) *Forest Tundra or Taiga*—which is transitional between treeless Tundra and fully developed Boreal Forest. (2) *Boreal Forest* (3) *Northern Hardwoods.*

Climatologists and ecologists differ on the names and exact boundaries of these zones, and they are essentially arbitrary divisions. Nevertheless, they serve as practical, recognizable areas in which the climatic conditions affecting vegetation growth are fairly constant, and in which the nature of the vegetation can be related to surface conditions with some validity.

In the following discussion the material will be grouped into these major climatic zones. Within each zone an attempt will be made to arrange the species, and associations of species, with reference to the types of terrain material that they indicate.

These groups are as follows:—

Rock and Talus.—An extremely coarse range of material, varying in size from small cobbles to very large boulders, primarily deposited as scree slopes due to rock fall from a free face, or as a boulder rich glacial material which has had the fines washed out.



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Sand and Coarse Materials.—Mainly sorted sands and gravels with little or no coarser or finer material intermixed. Characteristically associated with fluvio-glacial features, shorelines, some outwashed plains and most dune deposits.

Medium Materials.—Primarily material with a wide range of grain sizes, including

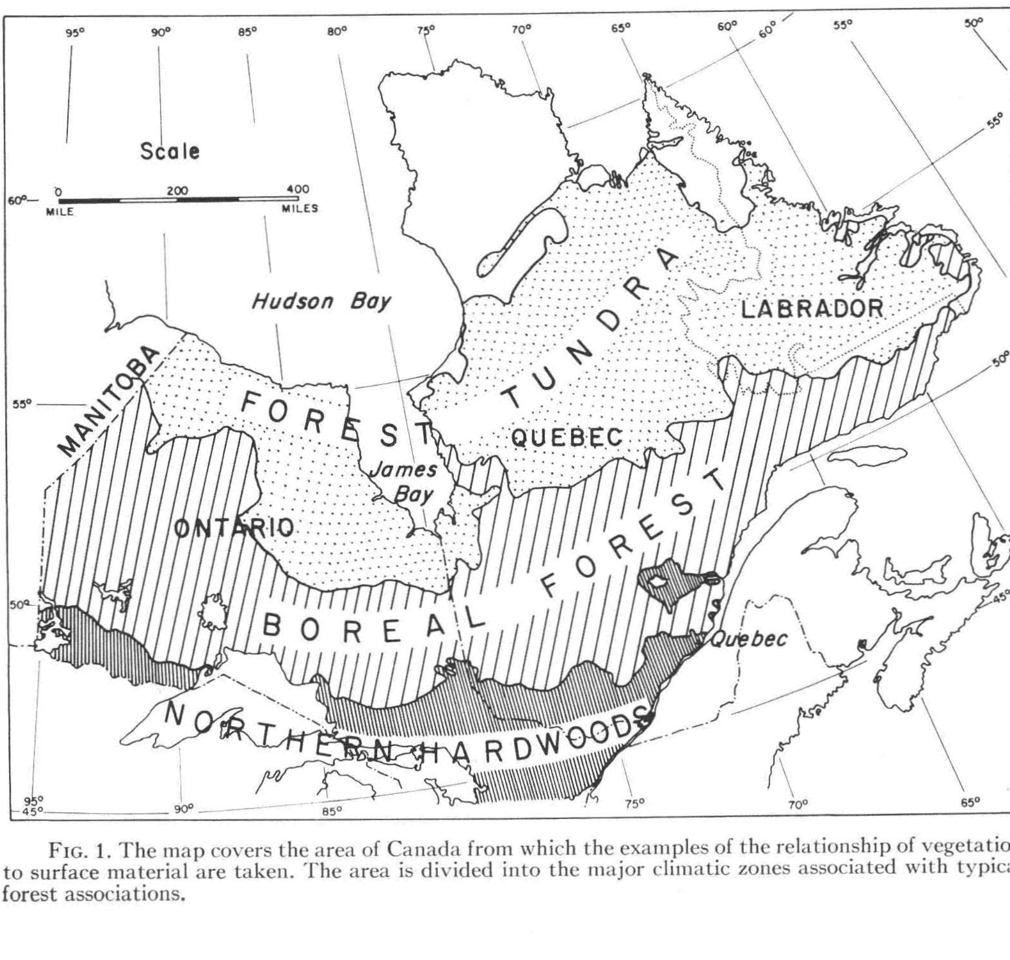

Fig. 1. The map covers the area of Canada from which the examples of the relationship of vegetation to surface material are taken. The area is divided into the major climatic zones associated with typical forest associations.

varying percentages of clay, silt, sand and coarser materials, forming a moderately well drained composite. Glacial till is the characteristic member of the group.

Fine Materials.—Essentially clays and silts of marine, lacustrine or alluvial origin, though they can include a glacial till with an extremely high percentage of fine material.

Peat and Bog.—Peat is regarded as vegetable matter only slightly decomposed and partly carbonised. Muck is considered to be partly decomposed organic material frequently interlayered with thin bands of silt. Bog and Swamp conditions often include both these categories with varying amounts of fine material and waterlogging.

It is fully realized that there is a continuous gradation of material size, and that such a broad grouping as this must necessarily be arbitrary. The grouping is essentially chosen for convenience in engineering practice, and each of the above groups may be regarded as having a characteristic application for engineering purposes.

Naturally, in many areas, woodland has been affected by fire. This is not such a drawback to the interpretation as may be expected, since regrowth after fire often has a greater dependance on surface conditions than later, slower growth. In commercially developed woodlands, however, where ground checking is impossible, the suggested relationships, while probable, must be used with extreme care.

Forest Tundra or Taiga Zone

The first area that can be discussed is the Taiga zone. It extends in a broad 100–150 mile fringe around Hudson Bay and James Bay in the western half of the region, and spreads to the east in a wide band across the peninsula of Labrador-Ungava between 52° N and 57°N. Within this area most lands are barren but combinations of Spruce, Dwarf Birch, Small Willow, Alder and dwarf shrubs and lichen can be found (Figure 2).

ROCK AND TALUS

Rock and Talus slopes are usually either exposed or lichen covered. In southern portions of the zone a Black Spruce, Balsam Fir association may occur on steep scree slopes which have a cover of 4″ to 6″ of peat and muck with water perennially seeping through the surface layers. The presence of Willow and Alder indicates up to approximately five feet of muck, frequently trapped in depressions on the slopes, with abundant aerated water seeping through the material.

SAND AND COARSE MATERIAL

Sand and Coarse Materials are not difficult to distinguish in Taiga areas. The coarsest gravels of terraces and fluvio-glacial deposits, with their excellent internal drainage, support the white or pale-grey open lichen pasture, with few or no trees. On material of medium size, particularly sandy till over bedrock which gives a dry, well-drained site, one finds open stands of Black Spruce. This "open lichen woodland," with the white or pale-grey lichen clearly visible between the trees, frequently outlines well-drained sandy terraces, eskers, sandy drumline, or coarse dead-ice morainic material. Kame terraces, with their variable material size and excellent drainage, are more often indicated by a profusion of Dwarf Birch.

MEDIUM MATERIALS

Dwarf Birch and Willow, with or without Spruce in association, are extremely variable in occurrence. However, they have been consistently noted on till material of medium to fine-texture where the surface configuration affords macro-climatic protection. Long slopes of loose, rubbly, medium-textured till are similar to seepage scree slopes described above. Mountain ash, willow and dwarf birch in association, locally indicate elevated, well-drained till areas, frequently with numerous outcrops of bedrock.

A reasonably closed stand of White and Black Spruce can occur on poorly drained alluvium in protected stream valleys, and in eroded channels on the north slopes of deltaic plateaus or rock-cored till hills where a thin layer of moss or peat has accumulated over the mineral parent material. It also has an affinity for the fine sand of coastal dunes. Deep sand dunes, stabilized and containing thin intercalations of organic matter, can sometimes be traced by reoccurrence of undifferentiated White Spruce. Numerous examples of White Spruce in this environment occur on the eastern side of Hudson Bay, and can be readily differentiated from the protected stream-valley environment on a basis of land-form analysis.

FINE MATERIALS

Grass and sedge have been noted on lacustrine and marine silts and clays in well-drained upland positions. This material, however, is of relatively rare occurrence.

Boreal Forest Zone

The Boreal Forest zone presents a strip 100–250 miles wide that runs from west to

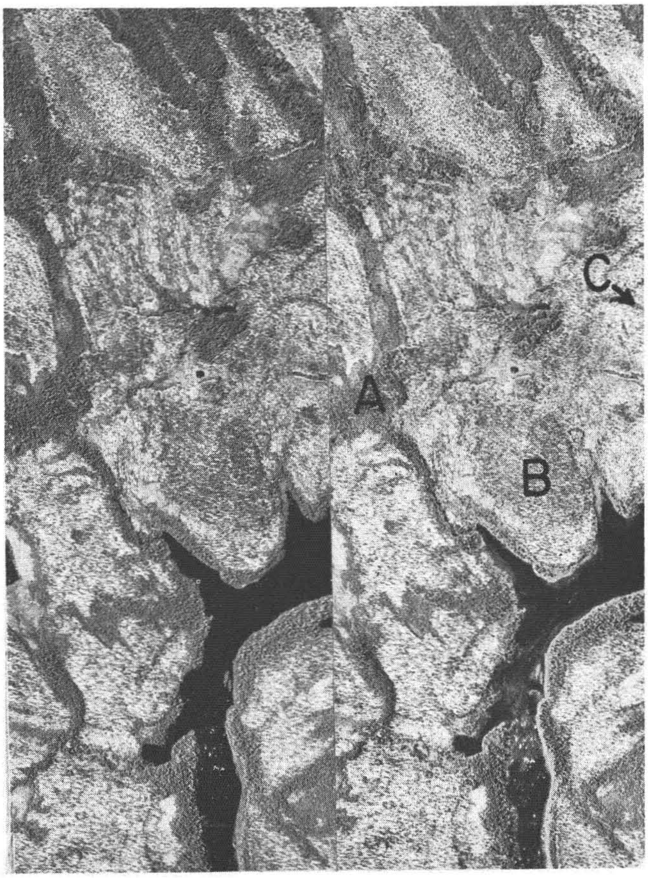

FIG. 2. Vertical air photograph in Forest Tundra area, scale 1,320′ to 1″ approximately, showing: at 'A,' a closed stand of Spruce on poorly drained, medium-textured alluvial material; at 'B,' open lichen woodland on sandy till; and at 'C,' open lichen woodland on a sandy terrace.

east, south of the Taiga. Its southern limit lies between 47° N and 48° N. It can be traced from the St. Lawrence immediately north of Quebec City to the west, where it cuts the tip of Lake Superior and passes into Manitoba just north of Lake of the Woods. This area has seen a great deal of economic and settlement expansion, particularly in recent years. Much of the mineral wealth of Canada is being exploited in this zone, with associated urban and hydroelectric installations. The "clay belt," which lies across the Ontario-Quebec border, is a rapidly developing agricultural area, and railroad and access road play an important part in this development. Nevertheless, the forest cover in the region is almost continuous. Photo interpretation problems are numerous, and the results of vegetation interpretation take on considerable significance.

ROCK AND TALUS

Rock debris is commonly covered with Black Spruce mixed with Jack Pine and White Birch. Talus slopes of this kind are typically composed of rock fragments of up to six feet in depth, mixed with patches of organic matter, over unweathered bedrock.

A heavy stand of White Birch can also be considered characteristic of boulder slopes, particularly when they are supplied with some seepage water. Very thin organic material, no deeper than one foot over bedrock, can support dense stands of Black Spruce in the eastern and western sectors of the Boreal Forest Zone.

SAND AND COARSE MATERIAL

The search for sand and coarser material is often demanded in rapidly developing regions. To the aid of the photo interpreter comes the species of Jack Pine, which in pure, dense, mature stands is probably the best indicator species of any in the Boreal Forest zone. Such stands typify sand or gravel material or dry rocky ridges, the differentiation being a matter of relatively easy landform analysis. Shorter, less dense stands of Jack Pine indicate drier and coarser, more siliceous material. Frequently this type of growth is found clearly outlining depositional terraces on valley sides. The shortest Jack Pine, in open stands, can grow on the poorest siliceous sand dunes.

A word of warning is needed at this point, as Jack Pine, after severe fire, can spread over practically any surface material. The above indicators, therefore, apply to mature, well-developed stands in most parts of the area.

An anomaly may occur in the western parts of the Boreal Forest where Jack Pine can grow on clay and silt. This may be related to special structures in the clay which in areas of low precipitation can give good internal drainage. While this latter case must be included for the sake of completeness, it can be stressed that the conditions are extremely unusual, and detract little from the value of Jack Pine as an indicator species.

Not as good as Jack Pine, but a reliable guide in the eastern half of the area, is Balsam Fir. This species commonly grows on excessively-drained sand, in areas of high humidity. The humidity in the eastern half of the area is the main factor controlling this indicator, as the species otherwise prefers moist conditions. Typical features outlined are river terraces and deltas (Figure 3).

MEDIUM MINERALS

In general the occurrence of White Spruce indicates glacial drift with a considerable silt and clay fraction. In most areas the drift so

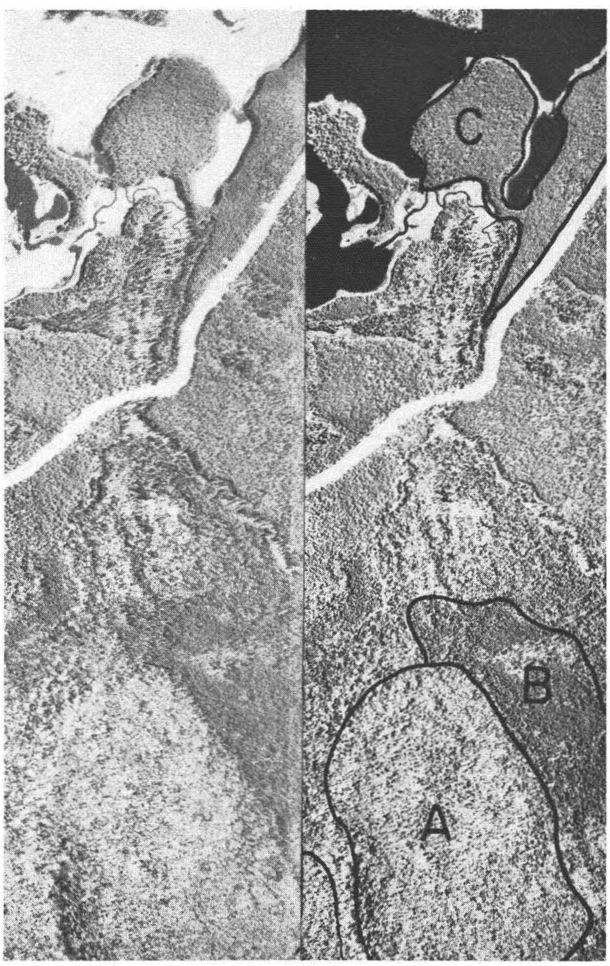

FIG. 3. Vertical air photograph in Boreal Forest area, scale 1,320′ to 1″ approximately, showing: at 'A,' a Balsam Fir, White Spruce, White Birch association on medium textured till; at 'B,' Black Spruce on shallow ($2\frac{1}{2}'$) peat; and at 'C,' Jack Pine on a sand terrace.

indicated varies in depth between three and six feet.

White Birch in a mixed stand is a good initial indicator of glacial till. The species associated with the Birch give further information regarding the nature of the till. Stony, light-textured tills have a characteristic Balsam Fir, White Spruce, White Birch association, while long slopes of uncompacted till are often covered with a Black Spruce, White Birch mixture. In the western part of the region, on a medium textured soil, the association is commonly that of well developed Jack Pine, Poplar and White Birch.

FINE MATERIALS

When White Spruce grows in association with large Aspen Poplar, the indication is of lacustrine silt or clay, or a silty till, often with a high lime content. Pure Aspen Poplar will occur after fire on any materials, but only in healthy stands on silts and clays.

Alluvial silts are differentiated by Alder growing in association with the White Spruce: such silts often have a percentage of organic material.

PEAT AND BOG

The occurrence of Larch, either in a pure stand or mixed with Black Spruce, is found to be the best indicator of peat. Peat under Larch is usually deep; a depth of six feet or more is common, as is the associated high-water table. In low-lying areas, pure Black Spruce may be used as an indicator of peat. Tall, mature Black Spruce is found growing over shallower peat (one to six feet). Usually clay underlies this peat, though the basement may be of sand or other materials. If the Black Spruce is short (20′) and mature, in a rather open stand, the peat is probably deeper, and in excess of six feet. Stunted Black Spruce associated with Dwarf Shrubs in this sector is an indicator of very deep peat. It must be noted that after severe fire, pure Black Spruce can enter and grow on most surface materials. This is, however, not too common (but it can be of local significance).

Northern Hardwoods Zone

South of the Boreal Forest the ameliorating climatic conditions allow a greater diversity of species, and the increasing occurrence of northern hardwoods. Naturally the greater number of tree types adds a measure of complexity to the interpretation. Some of the species have so wide an environmental range that they are of little or no value to the photo interpreter.

Others, while occasionally exhibiting a wide tolerance of surface conditions, definitely prefer a particular type of material. A very few have restricted growth conditions, and are limited to certain environments. Only the last group can be regarded as a true indicator species. However, the middle group—particularly associations of individuals within the group—can so often give an indication of the variations in composition and nature of any one type of surface material, and can so frequently act as confirmation of evidence derived from terrain analysis, that a selection of their number merits inclusion in this discussion.

ROCKS AND TALUS

Excessively stony conditions, either till slopes with the fine fraction washed out, or pure talus slopes, are indicated by the occurrence of Red and White Pine, White Birch and White Cedar in association. Yellow Birch can also be found frequently on these rock fragment accumulations. White Spruce can occasionally be noted on talus slopes, particularly in limestone areas. The extreme land form of this group, represented by ridge outcrops of bedrock, or, in the eastern part of this zone rock ledges, can bec overed with Red Spruce, and in the middle sector with Hemlock (Figure 4).

SAND AND COARSE MATERIAL

The transition from sandy-till to sand and clay, marking the outer edge of marine or lacustrine conditions, is often difficult to interpret from topographic evidence. However, the Yellow Birch and Sugar Maple of the till frequently give way to a White Birch and Poplar or a softwood association at the boundary line. The shoreline if predominantly sand, possibly shallow over bedrock, is more likely to be indicated by a pure Pine stand or by a pure open stand of deformed Poplar; also the trees become progressively taller and better formed as the shoreline grades downwards to the silts and clays of former deeper water.

Wet sand flats support Hemlock; slightly better drained moist sands favour White Pine. Red Pine is the true indicator species for dry, coarse sand and rock outcrop. It frequently outlines the larger river and marine sandy terraces and grows well on kames and eskers. Jack Pine is not widespread in the region, but is abundant in some local areas, and as in the Boreal Forest Zone, it indicates the driest and coarsest of materials.

FIG. 4. Vertical air photograph in Northern Hardwoods area, scale 200′ to 1″ approximately, showing: at 'A,' Sugar Maple of medium height (60–90′) on approximately 5′ of well drained sandy glacial till; at 'B,' a Yellow Birch, White Spruce association on imperfectly drained loamy till; and at 'C,' predominantly softwoods on lacustrine material.

MEDIUM MATERIALS

Glacial tills may be differentiated into "clayey," "silty," "sandy," "stony" and "shallow" varieties. Probably the best indicator of a deep, sandy-textured till is a tall (90′), well-formed stand of Sugar Maple. If the Sugar Maple is tall, yet crooked and defective, the till is usually poor and acidic, with an excessive quantity of stones. Short (30′–60′), stunted Sugar Maple with probable mixtures of Beech, Red Oak and Ironwood, shows that the till is probably very shallow over bedrock, or possibly sandy and very compact.

White Spruce appears frequently and usually indicates loamy lacustrine material or till. In the latter case it occurs in association with Sugar Maple, Beech and Yellow Birch. In the eastern half of the area an association of Red Spruce and Yellow Birch indicates a silty, stony and shallow till.

FINE MATERIALS

Within the Taiga and Boreal Forest zones vegetation analysis allows little differentiation of the surface conditions associated with clay and silt material. The diverse origins of such material are frequently of direct significance to highway and civil engineers. Heavy traffic on a road built across the plastic lacustrine clays will cause them to flow; "sinks" in the roadbed will result. To avoid this, the lacustrine fill may have to be excavated and replaced with materials which will not flow under heavy load.

Road cuts into otherwise stabilized slopes of saturated marine clays and silts, invite downslope movement of material that can be both costly and disastrous. Landslides and earthflows of this nature near Ventura, California caused not only the displacement of roads but the tilting of oil derricks, severe damage to the oil well casings, and breaks in pipelines (Putnam & Sharp 1940). The problem is also present in railroad cutting, canal construction and building foundations.

Compared with the lacustrine and marine material, a normal or "stony" glacial till, even with a relatively high clay and silt fraction, is a more favourable material for engineering purposes. But even in this material the height of the water table, which in many cases is related to the average grain size of the till, and the depth of till to bedrock, are of considerable engineering significance.

In the Northern Hardwood Zone, vegetation analysis can give some definite help in recognizing these differences in the clay and silt group.

The occurrence of Elm is a useful indicator of clay material. It occurs in abundance on lacustrine and marine clay flats, but it can occasionally be found on alluvial silts with a high muck content. It is thus a very good indicator of poor roadbed conditions. Along the northern fringe of the zone, Poplar is another species that frequents clay and silts. In this case the preference is commonly for lacustrine clays and silts, usually with a substantial silt content. For the photo interpreter an excellent negative indicator is Sugar Maple, in that its presence rules out the possibility of either lacustrine clays and silts or marine clays. Soft Maple on the other hand is abundant on these materials and has a different tone and texture on the photographs from that of Sugar Maple.

BOG AND PEAT

Swampy muck and peat conditions are indicated by the occurrence of White Cedar in an association that may include Black Ash, scattered White Elm or Swamp Maple.

Black Spruce can be regarded as the true indicator of the Peat Swamp, exactly as in the Boreal Forest Zone. However, in this southern zone Black Spruce is rarely found outside the wetter, more acid swamps, where the material itself is peat rather than a mixture of muck and peat.

LIME INDICATORS

To some extent, lime-rich rocks can be recognized by forest analysis. The smaller vegetation is a much better reflector of these conditions, but short, stunted Red Oak is also commonly found on Limestone outcrops. This species also exists on granite in a dry area, though the presence of limestone may be suspected in the vicinity. White Cedar is an indicator of lime under many conditions. The wide variety of such lime-rich surface materials includes fine textured upland soils, rock and talus slopes, muck swamps and even sand dunes. Occasionally the White Cedar occurs in a mixed association with White Spruce, White Pine and Juniper. This association indicates bedrock limestone at, or very near, the surface.

CONCLUSIONS

The recognition of various tree types is naturally essential, if this approach to material interpretation is to be used. Several excellent publications covering this aspect of photo interpretation have been published in the last few years, a considerable number of which were detailed in the September 1961 issue of PHOTOGRAMMETRIC ENGINEERING. A direct reference to Air Photo Interpretation of the species in the area covered by this paper is in "Recognition of Tree Species on Air Photographs by Crown Characteristics, by L. Sayn Wittgenstein, Canada Department of Forestry, Forest Research Division, Technical Note 95, 1960," which was published in part in the December 1961 issue of PHOTOGRAMMETRIC ENGINEERING.

On first sight there would seem to be a major obstacle to engineers, geologists and interpreters who are not specifically trained in forestry. In practice, however, it has been found that recognition of the relatively few true indicator species is soon mastered and that their relation to surface material is immediately discernible. The associations of species and secondary indicators are assimilated as problems of interpretation arise. To assist in the initial step toward specie identification, a short list of publications dealing with the recognition of tree species from air photographs has been added to this paper.

Accuracy in species interpretation depends to a great extent on the scale of photographs available. Recognition of species at scales smaller than 3,000 feet to 1 inch is by variation in tone; such photographs are commonly used in regional landform interpretation; the frequently used scale of 1 mile to 1 inch comes in this group. On larger-scale photographs, recognition of species by crown shape is possible. 2,000 feet to 1 inch was found to be the smallest convenient scale for crown shape analysis, and even at this scale recognition of the smaller species must rely on tone differentiation. 1,000 feet to 1 inch is probably the optimum scale, and the smaller species such as Alder show up well. It can be noted that the readily available photographs of 1,320 feet to 1 inch closely approach the optimum.

It must be stressed again that the relationships between forest vegetation and surface material presented above are not definite laws. Rather, they are the averages of a continued series of observations that have been proved valuable in photo interpretation practice. In transition belts between the suggested climatic zones, great care must be used, and all possible topographic data must be incorporated in the final analysis. In areas of considerable vertical extent it must be remembered that there can be a transition of climatic zones upwards as well as laterally. This applies particularly between the mild Northern Hardwood Zone, and the cooler Boreal Forest Zone in the area discussed. Despite these necessary limitations, the method of vegetation analysis in terms of surface material can add substantially to the accuracy of terrain studies; it is submitted as a valid addition to the criteria available for the interpretation of surface material.

Acknowledgement is herewith made to the efforts of the Ontario Department of Lands and Forests and also to Professor K. B. Jackson of the University of Toronto. They have investigated air photo technique for the purpose of increasing tree crown detail in the negative. Resulting photo prints are yielding much greater information on species identification than normal air photography.

Suggested References for Identification of Tree Species on Air Photographs

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Sayn-Wittgenstein, L. (1960) "Recognition of Tree Species on Air Photographs by Crown Characteristics": Canada Dept. of Forestry, Forest Research Division, Technical Note No. 95. 1960, 50 pp.—Republished in part in Photogrammetric Engineering, Vol. 27, No. 5.

Evaluating Color, Infrared, and Panchromatic Aerial Photos for the Forest Survey of Interior Alaska

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(Abstract is on next page)

Interior Alaska has extensive, remote areas of brushland, tundra, and barrens intermingled with scrub timber and better hardwood and softwood stands, both pure and mixed. Congressional authorization for a forest survey of Alaska brought new challenges to the U. S. Forest Service. Time, costs, and practicability pointed to major use of aerial photos for data on area and timber volumes.

With such great emphasis on photo sampling, the choice of scale, focal-length, and film-type are important considerations. A scale of 1:5,000 and a 12-inch focal-length was selected for this project.‡ Raup and Denny,[8]

‡ Wilson, R. C. "Working Plan for the Forest Survey of Interior Alaska." U. S. Forest Service, Washington. 1957. (Unpublished report.)

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