Screenings from the Soil Research Lab

IOWA ENGINEERING EXPERIMENT STATION
IOWA STATE COLLEGE, AMES, IOWA

May - June, 1959
Vol. 3, No. 3

ALL UP IN THE AIR (looking down)

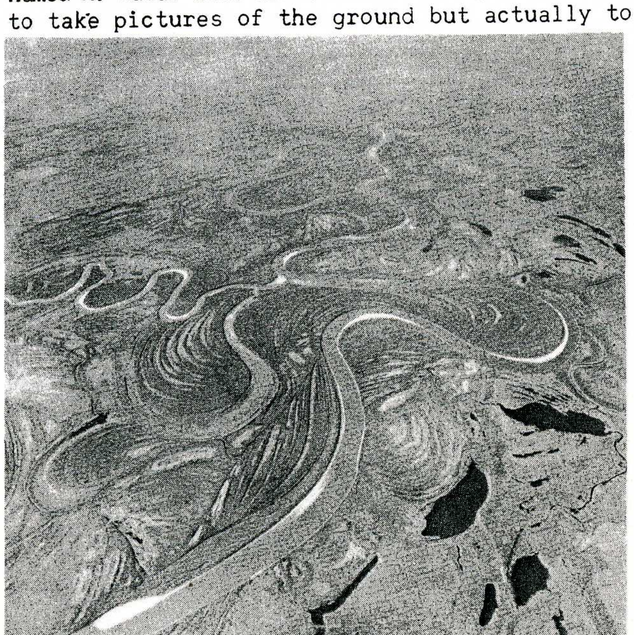
The straight dope on aerial photography

Eureka and Banzai! Avast and Ahoy, all you bicipitous beard-tuggers, here comes another centennial--one we'll bet you've missed.

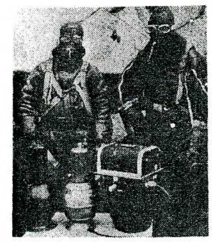
Slightly over 100 years ago, 101 as a matter of fact, was invented the greatest boon to surveying since the hatching of the first civil engineer in yon early Paleolithic.

We refer to the inception of the most widely used tool for modern mapping, the aerial photograph. True, aerial photography took a while to catch on, but it's not the end of a pregnancy that gets the credit. Necessity may be the mother of invention, but invention also needs a father. The fatherly basic research is mostly for pure fun. Necessity then comes along and dictates the drudgery of perfection.

In 1858 a daring Paris photographer-aeronaut named A. Nadar went aloft in a balloon, ostensibly to take pictures of the ground but actually to record the merits of some jeunes filles sunbathing on the roof of the nearby Hôtel George V.



Oblique air photo of Koyukuk River, central Alaska. Oblique photos may be corrected to vertical for mapping, but are used mostly for reconnaisance because of fogginess near the horizon. Loopy scarred areas are sand bars.



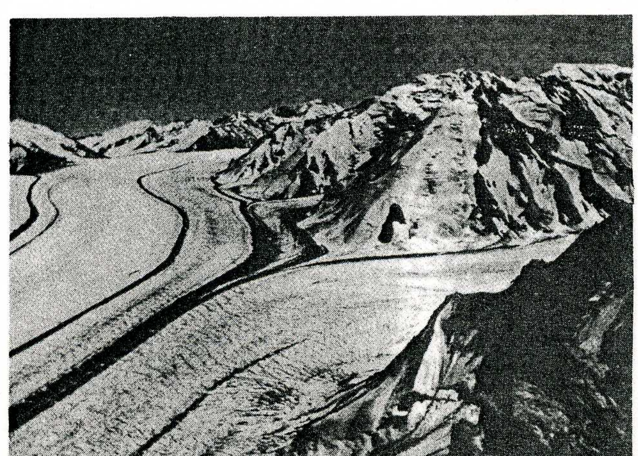
High-flying photographers, c. 1927. Brr, those open cockpits. Aerial camera on the left, oxygen bottles on the right.

As usual, science lagged behind art, and the wet collodian photographic process required fast work to get an image. With astute dedication to purpose (j'aime those jeunes filles), by 1863 Nadar had built himself the biggest gas balloon in existence, complete with two-story basket chemical laboratory. Unfortunately this time the basket was too large, and his wife went along. The paths of research are ever precarious, especially when efforts become unwieldy.

More fatherhood

Meanwhile in 1851 another Frenchman, Col. Aimé Laussedat, was busy siring photogrammetry, or use of photographs for mapping.

Actually Laussedat's photographs were taken from the ground. After the normal gestation period of 50 years, necessity again became a mother, and a Canadian named Deville resurrected photogrammetry and invented a stereo plotter.



Phototheodolite picture of a glacier in high mountains of Tadzhik, S.S.R., north of Afghanistan. Uncomfortably cold for using a transit. Date, 1928.

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By the start of the Great War the use of the so-called phototheodolite (camera) and stereo plotter was a wild success. Photos taken on the ground from both ends of a measured base line were viewed in a plotter, and from the difference in angle of view each visible landmark could be pinpointed directly on a map. This eliminated a lot of field note-taking and eyeballing through a transit.

Unfortunately with photos made from the ground a lot of landmarks remained behind hills. Conditions were ripe for somebody to come up with something else.

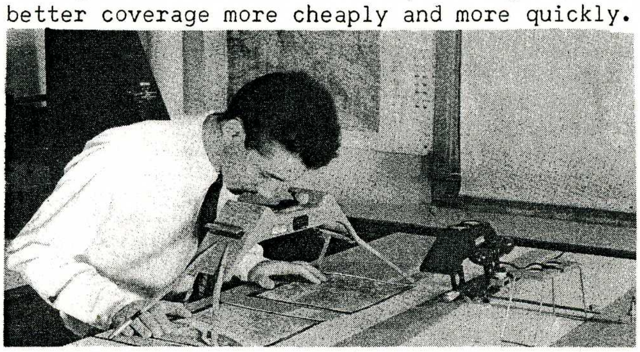
Enter the airplane

In 1909 a daring young man took some pictures from his homemade flying machine, perhaps to bring home some of the thrill of flying. His name was Wilbur Wright; you may have heard of him before.

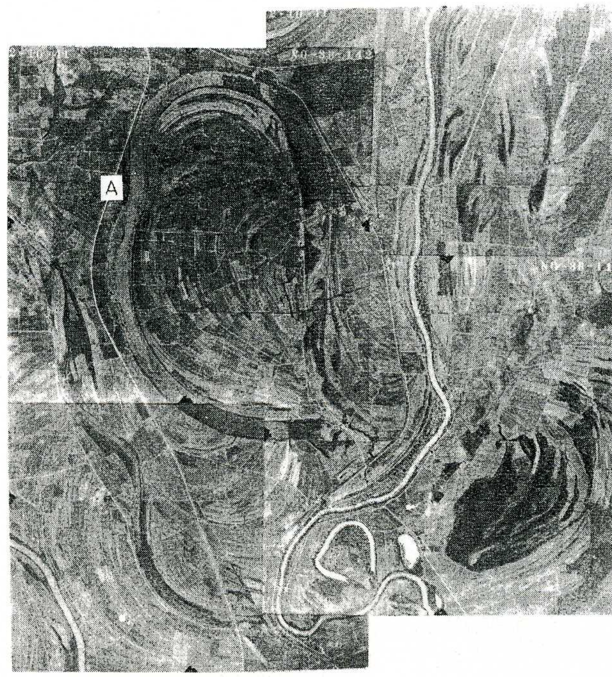
Within a very few years hostilities commenced, and armies took to the air. Fliers threw bricks at one another and also took a few pictures. The pictures proved far more damaging than the bricks, and not only proved the merit of aerial photography, but did much to make the airplane. Vertical shots gave up-to-date maps where you could almost see the spike on Heinie's hat. Techniques were developed to make interval sequence shots to give continuous photo coverage along a flight line, and parallel flight lines could be laid out to give complete coverage of an area.

Exit the phototheodolite

Air photos spelled doom for the phototheodolite almost before it got started, and the special cameras and accompanying stereo plotters were fair game for museums. Air photos gave much better coverage more cheaply and more quickly.



Turkish engineer Turgut Demirel sees living stereo with a modern mirror stereoscope. Black instrument in front is a stereometer, combining stereoscope, parallax measuring device and (on long arm) contour pen. Small instrument on wire legs is a lens stereoscope.



A photo mosaic. Time, tide, and rivers like the Mississippi move on but leave their marks. Here near Vicksburg scars run deep, and show on the surface. Scarred areas are sand, covered with variable amounts of flood-deposited clay. Abandoned meanders contain clay, or "clay plugs." Old plugs are hard for the river to erode; they put jogs in the river (A), and eventually cause new cutoffs.

What of the transit?

Now the majority of mapping is done from vertical aerial photographs, and the use is rapidly increasing. Decline of the older surveying methods is reflected in engineering college curricula across the country, partly to make room for more science and math, you lucky future students.

Older methods of surveying are far from dead and can never die so long as highways go where the stakes are. You can't drive a stake with an air photo. Furthermore ground surveys are necessary to establish control points, as it is otherwise impossible to accurately determine the scale of a photograph. For one thing scale depends on flight altitude, and airplanes don't run on a track. Terrestrial surveying is still the thing for high accuracy or for small areas not already flown or for areas observed by such things as trees or girls dormitories; in the latter instances air photos are practically worthless.

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BIG SWITCH TO STEREO

To hark back a little, you may recall the thrill of seeing and almost feeling mountains, parks or monuments, by slipping a picture card in the old parlor stereoscope. Perfected by Oliver Wendell Holmes, who was famous for other reasons, it practically revolutionized the entertainment industry in the 1890's. Then about 1915 came movies; goodbye stereo. Stereo movies returned in the '30's and '50's, but apparently people didn't like their curves through goggles.

3D from the air

The usefulness of air photos and much of their enchantment comes from their adaptability to stereo vision. One can look at a pair of photos and get tremendous depth. Houses appear as castles, valleys become deep, sinuous canyons, and trees look like marshmallowy blobs suspended in the air on toothpicks. It's enough to make one airsick, or at least a little woozy.

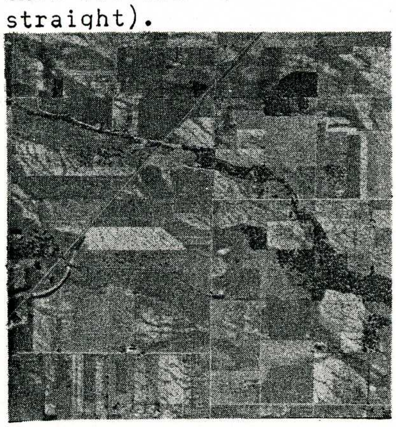
Actually the stereo effect is like something you'll never see from the air because depths are greatly exaggerated. Our eyes see depth because they view an object from slightly different angles (Euclid, 300 B.C.).

Normal eyes are two to three inches apart depending on the fatness of the head. Air photo pairs are often taken miles apart. Therefore the angle difference to an object, or parallax, is greatly increased, and heights of hills are exaggerated thousands of times. It's much like looking at a model.

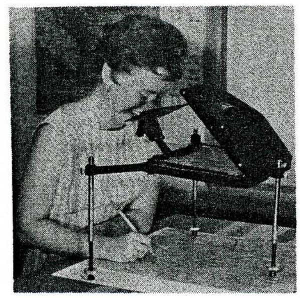
Maps

One way to make a map from air photos is to trace, like in kindergarten.

Unfortunately if no correction is made for parallax or elevation differences of the airplane the photos won't match, and straight roads will show crooked (or crooked roads will show straight).



Sand and gravel, we'll bet. Looks like a braided river without the river. Glacial outwash, Indiana.



Maps can be corrected for photo scale differences or tilt by mounting the photos in a vertical sketchmaster. Mirror system allows you to see photo and map table at the same time. Wheee! Miss Jones.

A number of correction schemes have been devised. One method assumes that angular positions of objects from the center of the photo are correct, but distances may be off. Radial slots are punched through landmarks in common to overlapping photos; then when two photos are overlapped, pegs are inserted common to both slots, and distances are fixed by the two or more angles. Minor adjustments are made to tie in with ground control.

Contouring

Our final bit on photogrammetry is to tell about preparation of contour maps from photos.

If you lay the two photos of a stereo pair side by side and get out your ruler, you'll find that corresponding points on the two photographs are not all the same distance apart. Due to angular parallax, a hilltop will measure closer between photos than will two corresponding points in a valley.

From this difference in distance, or parallax, p, one can get the height of the hill:

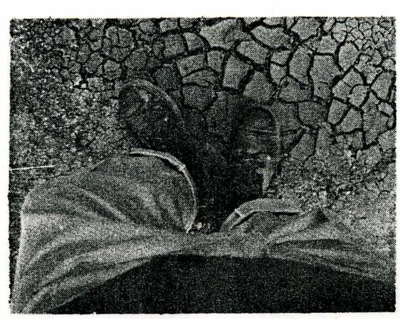
$$H = \frac{p \times \text{altitude of plane}}{p + \text{photo base line}}$$

The photo base line is the center-to-center measurement corresponding to the distance the plane travelled.

Example: p = 0.10", A = 10,000', b = 4.0".

$$H = \frac{0.1\ (10,000)}{4.1} = 234'.$$

For better accuracy a simple measuring device, variously called stereometer, parallax bar, stereocomparator, or peek-a-boo, puts the photos



Replica of the very first vertical air photo, two feet above the ground.

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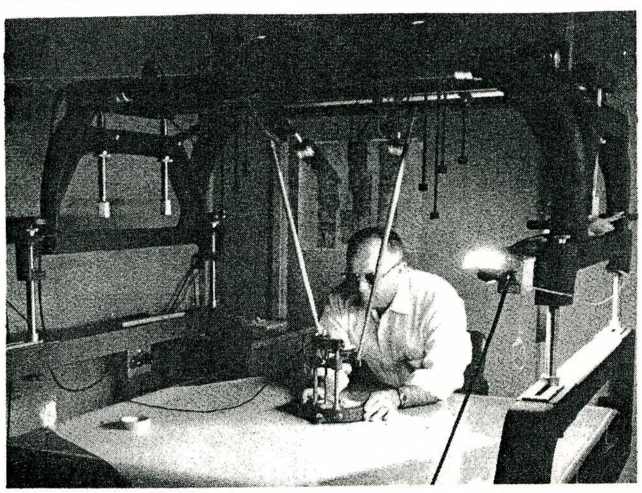
under a stereoscope so both are seen at once. Distances are measured by means of two dots, one placed on top of each photo. The interdot distance is adjusted so the dots are at corresponding points on the two photographs; they then appear to merge, and the distance may be recorded. The adjustment usually employs a micrometer for fine accuracy. When the two dots are not at corresponding points they appear as two, or the eyes may compensate so they appear as one but it is either floating in space or buried in the ground. Hence the term "floating dot;" another optical disillusion.

If the stereometer is moved over the photos so the floating dot is always exactly on the ground, the dot is following a line of equal elevation, or, in the parlance of the professional, a contour line (science). Usually a mechanical hookup is made to simultaneously draw a contour map.

More elaborate methods use projectors which project alternate photos in red and blue. Viewing with a red lens - blue lens pair of glasses gives the stereo image. A floating dot or cross is added optically on a surface of small movable stand, and made to fall on the intersection of rays from the projectors by varying the height of the stand. If the height is adjusted for a certain elevation, the stand can be shifted around so the dot stays on the ground and thus follows a contour. Add a drawing attachment and you get a map. If the dot is too high it "floats" stereoscopically, or if the eyes focus on the ground it will appear as two.

Accuracy? Ordinarily error is less than one half a contour interval, and the minimum contour interval is about 1/500 of the flight altitude. For a 10,000 foot flight, 20 feet.



C. L. Hutt of the Iowa State Highway Commission draws contours with a Kelsh plotter. A similar apparatus called a Multiplex, projects a series of photos to allow fitting or "bridging" of photos between ground control.

Shale lends itself well to erosion with a dendritic stream pattern. In the upper right portion of the photo shale has been stripped from a more resistant bed, probably sandstone.

AIRPHOTO MAPPING OF SOILS

Entirely apart from aerial surveying, air photos have a happy heart for showing rocks, soils, vegetation, houses, gun emplacements, etc. Between wars geologists make much use of photos to study rock structures and locate likely spots for oil.

Use of photos to map soils was pioneered by the U.S.D.A. Soil Survey, which soon found that photos are a reliable accessory, but they surely don't tell all. Air photos are now used as base maps for nearly all agricultural soil mapping. Soil boundaries often follow color or erosion breaks on the photos.

More recently soil engineers have picked up air photos as their Magic Tool. Under experienced eyeballs, air photos can be extremely valuable to locate everything from gravel deposits to landslides. Usually the soil type in any given area can be guessed at if not positively identified. However, to remove the guesser from the possible category of ignoramus he had better have all clues possible, in the form of geological reports, soil survey reports, and, preferably, field experience in the area being mapped. Also nice is the opportunity to field check the maps before somebody else does. Profitable mistakes improve the art. Other mistakes could destroy it.

Interpretation

Soil areas are best categorized by parent material, or, to be strictly geological, rock type.

For example, igneous rocks are those hard, crystalline head splitters that were once probably melted. They usually come in two varieties, granite, light-colored and coarse grained, and basalt, dark-colored and fine grained. Granite areas are shown on air photos by extensive frac-

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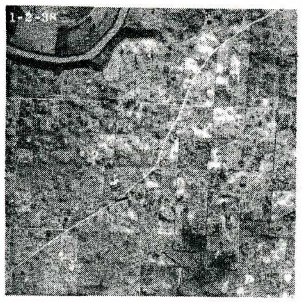
ture patterns. Fractures in turn influence drainage, and make streams run straight and turn square corners.

The most familiar basalt is lava, which spews forth from volcanoes. Just as spectacular from a soils standpoint are basalt lava plains, built up by quiet eruptions from fissures. Both types of flows give a typical bubbly, crenulated or taffy-like appearance on photos.

Sedimentary rocks

Common sedimentary rocks are limestone, sandstone, and shale, often interlayered. If they lie flat the drainage pattern is dendritic; it branches upstream like twigs on a tree. Often the softer shale is stripped off by erosion, exposing harder ledges as cap rocks. Result, flat-topped mesas or buttes with resistant rocks on top.

A giveaway on limestone areas is the occurrence of collapsed caverns, or sinks. Note how fine drainage lines lead to the sinks, some of which contain water. →



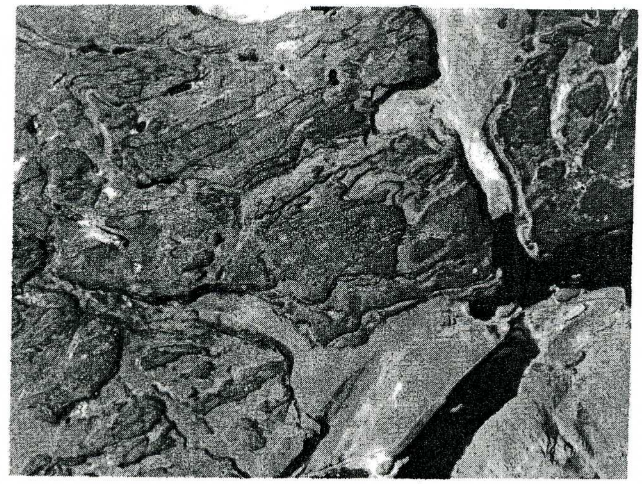
Sedimentary rocks are not necessarily sedentary rocks, for they are often tilted or folded into patterns reminescent of network trouble on TV. Inclined, resistant layers stand up as ridges which bend drainage lines into a parallel, trellis pattern. If the rock sequence is known, mapping is simple, because the harder rock layers resist erosion and stand up as sloping ridges, or hogbacks. Between is often shale.

SEDIMENTS

Whereas rocks are political stalwarts, sediments are the vast unconsolidated masses, identified by group, easily manipulated, and inherently unstable and dangerous to the unwary. Certainly the most important civil engineering "soils" are the recently deposited, unconsolidated sediments. Some are similar in origin to sedimentary rocks but most are not; most are land deposits by wind, water, or ice.

Wind

Wind deposits are sand or silt, although some people take exception to the silt.[1] Sand dunes are easily recognized by curvaceous form, mobililty, and excitement[2]; or in stable, vegetated areas the shape gets old and sloppy, and may show wind eroded pock-marks or blowouts.



Regional, almost horizontal lava flows, aptly termed plateau basalt. Streams have cut through the layers. Columbia Plateau, northwest U. S.

Silt is easily eroded by water. Where thick it gives land a distinctive badlands appearance. Stream cuts are often near vertical, but this is not a universal criterion. The best way to map silt, or loess, is to already know it's there, then look for signs.

Ice

Glacial deposits cover much of Europe and North America.[3] Moraines are usually poorly drained and present a mottled appearance on photos. Special forms, such as drumlins (elongated hills), eskers (sinuous gravel ridges), kames (conical gravel hills),[3] etc., are easily recognized.

Ice water

Water from melting glaciers swelled major streams and made gravelly floodplains which now stand as terraces.[2] Very important to engineers. However, many terraces are low and more easily spotted from the ground than from the air photos, once you know where and how to look.

Other ice water was dammed up, making large lake basins which quickly filled with sediment. Very big, very flat, but with beaches.[3]

River water[4]

River deposits are exceedingly susceptible to mapping from air photos because of the beautifully drawn slashes and patterns.

Rivers fall into two categories, braided[1] and meandering. Braided streams are heavily loaded, have high gradients and fast water, and mostly leave sand and gravel. Meandering streams are

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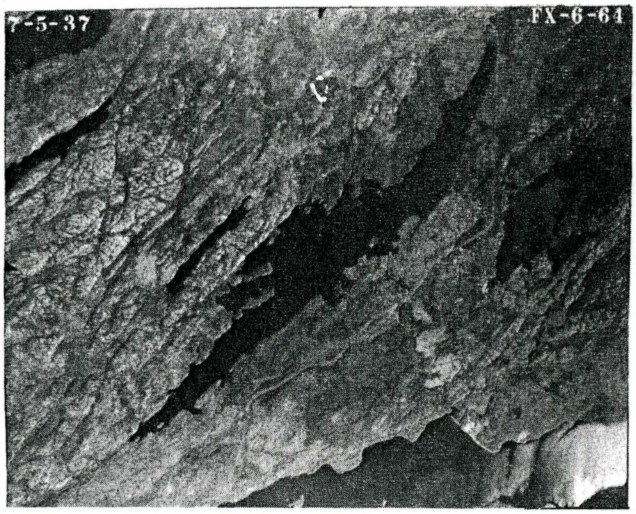


Granite or similar rock unmistakably revealed by the fine fracture pattern. Elongated lakes are from glacial scour. This is a shield area, extremely old and practically level from prolonged erosion.

slower and more orderly about their deposition; sand goes inside the meander loops; silt and clay fill abandoned oxbows or sludge up the floodplain during flood.

<u>Local alluvium and fans</u>

In tiny streams much of the sediment has merely moved down from the hills. It is still hill folk, little changed by its translocation. Call it local alluvium.

Other sediment is carried along for a while, then dumped most ungraciously when the river gets tired, usually because it runs out on a plain. The result is an alluvial fan. Very important, and often a site for roads. Desert basins are practically filled with alluvial fans. While fans are identifiable on photos, their subtle changes in slope are often more easily seen from the ground.

<u>Deltas, beaches, and coastal plain</u>

When rivers hit quiet water they really relax and drop everything. Result, a delta.

Reworking of delta material by waves gives sandy offshore bars and beaches, and helps wash finer material farther out.

Bordering the oceans are broad, flat, recently emerged sea bottoms called <u>coastal plains</u>. Materials are mostly fine, which is why there's a lot of clay in east Texas. Usually very flat and featureless on air photos. Older, inland sections of coastal plain are actually sedimentary rocks and give similar outcrop patterns, except the "hogbacks" are low, and called cuestas.

MODIFICATIONS

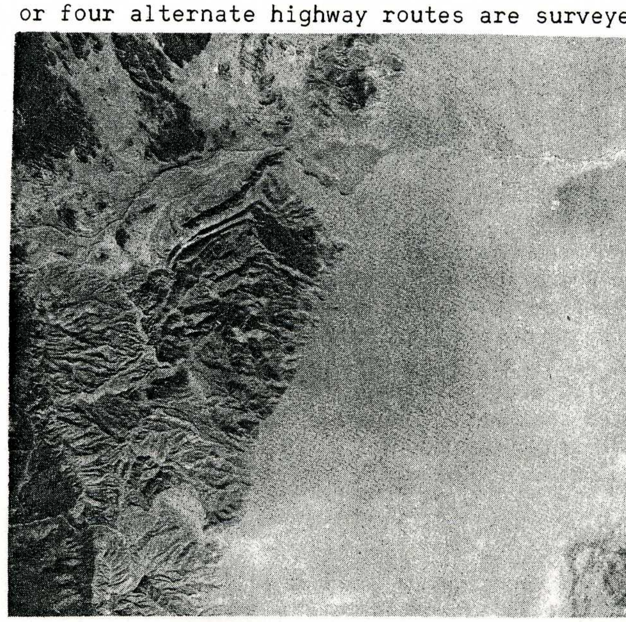
Life is sweet but life is wearing, and the most important change in soil parent materials is weathering and formation of a soil profile. Here local knowledge is essential before you even whisper air photo.

In general, weathering depends on climate, and profiles are classed into great soil groups.[5] Local areas where climate doesn't control are more obvious; wet spots or alkali spots are readily seen on air photos by dark or light color, respectively, and occurrence in depressions. Very poorly drained depressions may have peat bogs, revealed by a unique ringed appearance.

Another type of modification so evident it tugs the heart is the effect of permafrost, which makes flat ground look like bad paint, all cracked and ready to peel.[5] Cracks are occupied by ice wedges. In permafrost border areas the ice wedges are deep and don't show, either on the ground or on photos.

OVERALL DOWNLOOK

In industry and in highway engineering automation is the latest word, and one man with photos and a plotter can automate quite a few survey parties into other jobs. Often three or four alternate highway routes are surveyed



Alluvial fans (right) dribbling out from the mountains, Palestine. Note tilted sedimentary rock ridges, and at upper left, fracture pattern characteristic of granite.

from the air without anybody outside of the office even knowing about it, thus eliminating much of the lobbying and political windjamming connected with selection of a final route. The saving in noise alone makes photos worth considering.

Actually aerial surveying is not true automation. However, if you throw in the services of an electronic computor, which compiles elevation data and computes earth quantities quicker than a fast-acting headache remedy for humans who used to do the same thing, you've got a real engineering organization. Add another machine which takes elevation data and automatically draws cross sections and even tells itself how many to draw, and most of your engineers can stand around the Coke machine, in theory at least.

Unfortunately a machine has not yet been invented to interprete air photos, identify soils, and locate highway routes to avoid trouble spots. This is a wide open field waiting for experts with plenty of new how. Eventually photo interpretation information along with elevation and grade data may be funneled directly to a computor which would calculate not only total earth quantities, but different kinds of earthwork--rock, topsoil, clay, etc.

<u>Footnotes</u>

Many of the air photo glimpses of soils offered here are discussed in more detail in other Screenings.

1 Wind-blown silt and loess, Vol. 1 No. 4
2 Sand, Vol. 3 No. 2
3 Glacial deposits, Vol. 2 No. 5
4 Alluvial deposits: Next year?
5 Alaskan great soil groups and permafrost, Vol. 3 No. 1

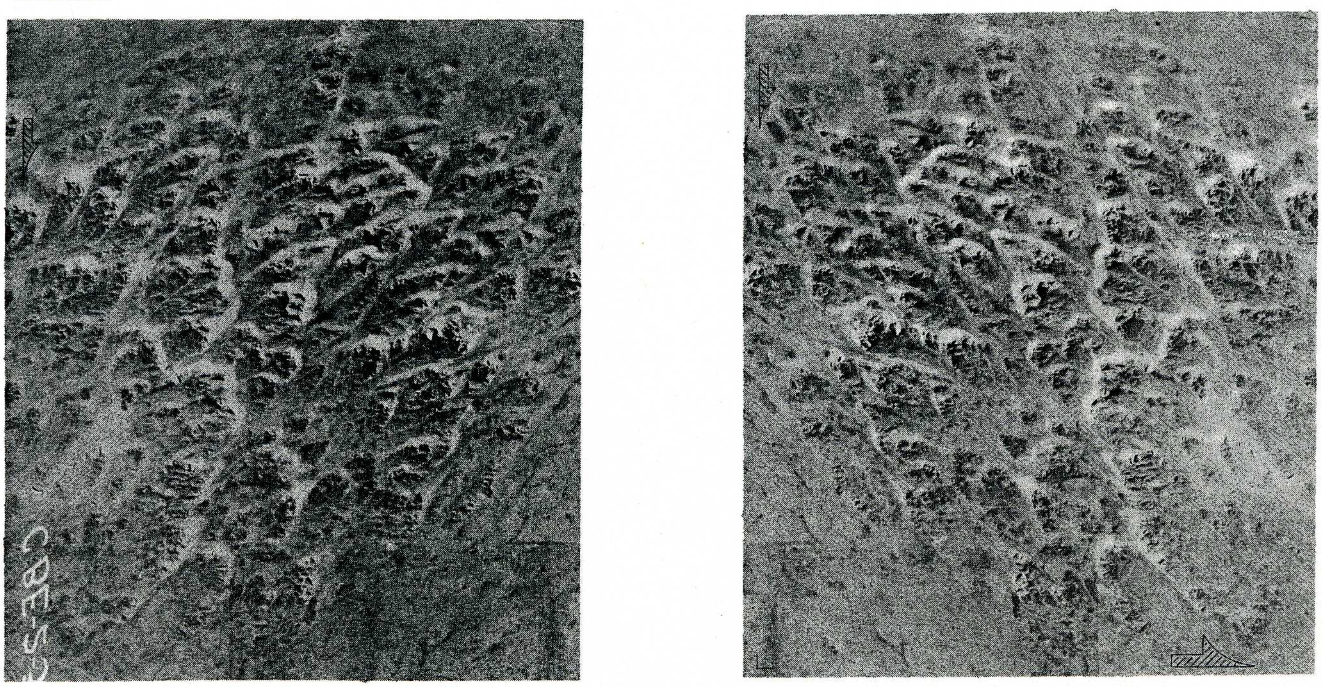
ACKNOWLEDGEMENTS AND REFERENCES SIGHTED

Leading the way in the fields of photo interpretation and photogrammetry for highway engineering have been Purdue and Cornell Universities, M.I.T., the U. S. Bureau of Public Roads, and several state highway departments, most notably California and Ohio, not to overlook some tremendous pioneering by the U.S.G.S. and U. S. Coast and Geodetic among others. For further dope see <u>Manual of Photogrammetry</u>, 2nd Ed., 1952; Highway Research Board Bulletins 157, 180, and 199; and <u>Photogrammetric Engineering</u>. Soil identifications are outlined by D. J. Belcher, "Engineering Signficance of Soil Patterns," Proc. Hwy. Res. Bd. 1943, and nicely illustrated in CAA Preliminary Technical Development Report No. 52, App. B, 1946.

Iowa Eng. Exp. Sta. research in soils is under HRB Project HR-1 sponsored by the Iowa State Highway Commission.

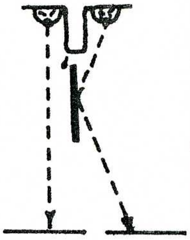
RLH

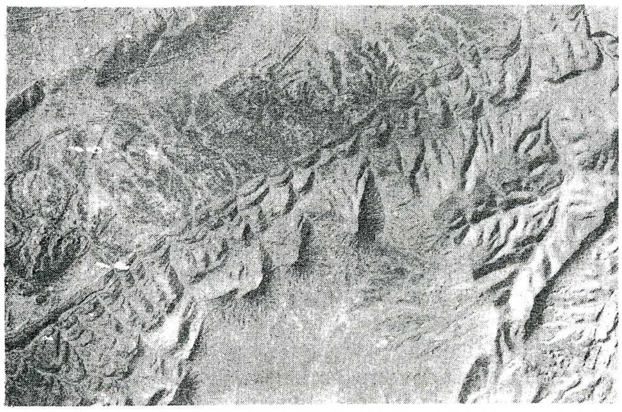
Turn the page for instructions for vivid stereo. Stereo pair below shows blowouts in stable sand dunes, western Nebraska.

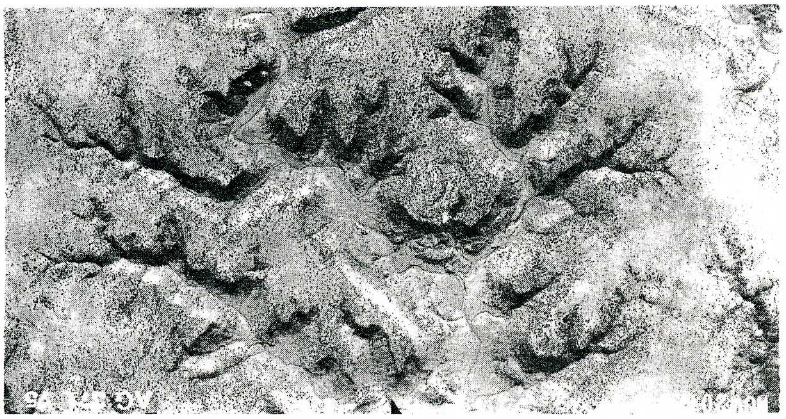


THIS PAGE FOR STEREO

Needed: One pocket mirror. Hold the mirror edgewise vertically between your eyes so one eye looks directly at a photo while the other one sees the companion picture in the mirror. Are you seeing double? Good! What a cheap drunk. Once you see double, the images are moved to superposition by tilting the mirror sideways. Suddenly, stereo! Wow? One-eyed persons out of luck.



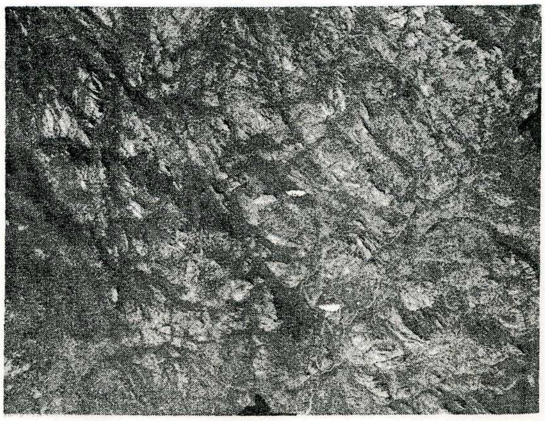




Flat-lying sandstone cap rock over softer shale. Dentritic drainage pattern. Colorado, U. S. A.

You name it. Clue: fracture pattern. Black Hills, South Dakota.

Tilted sedimentary rocks forming hogbacks. Upwarped area to the left is called an anticline; the center has been eroded out. Very typical. Locale, W. Algeria.



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