on each bed, and (e) the final contours as shown. The most impressive result of this example is the success of the free-style reconnaissance contours, in bringing about the discovery of the locations, approximate dimensions, etc., of the structural features of interest, particularly the anticlinal flexures which are marked. The discrepancy of strike along the extreme west edge is indicative of faulty estimating of both horizontality and strike along the edge in the reconnaissance version, and failure to get the benefit of extending the work in this direction.

SELECTION OF AERIAL PHOTOGRAPHS FOR TEACHING GEOLOGY

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INTRODUCTION

FOR several years the University of Illinois department of geology has been assembling a collection of aerial photographs for use as teaching aids in elementary physical geology, geomorphology, structural geology and for research. The collection now numbers more than 5,000 photographs and several hundred photo-index sheets and mosaics.

Selection of particular photographs desired for the collection has generally been made through ordering photo-index sheets of desired areas, and selecting from them outstanding or especially typical photos of the region in question. In some other cases, visits to photo laboratories of government agencies, where albums of photo-indexes are on file, aided in discovering outstanding groups of photographs. Some areas were selected because of familiar topographic maps which have for years been used to illustrate certain types of land forms in laboratory teaching. In some such cases the photo proves to be surprisingly unlike the map. Thus the Moses Lake, Washington quadrangle, shows only regular crescentic barchane sand dunes, whereas the photos show various combinations of barchanes, longitudinal seif dunes and transverse dune ridges, correcting an erroneous impression derived from the map. Many other areas selected were based on personal familiarity by members of the staff. Lists of outstanding aerial photographs for geologic use have been issued by the Air Forces* and by the Geological Survey of Canada.†

Although the search for outstanding or good photographs has been in a sense haphazard, and no doubt many equally suitable or even better photographs exist which have not come to our attention, this short paper calls attention to some of the more satisfactory photographs in the collection. A complete subject index of the collection has been prepared, and copies of this may be secured by interested persons through writing the author of this paper. A selected list is in the course of preparation for distribution to geology teachers by the American Geological Institute. It is hoped that it will be available within a few months.

The prints have been ordered on semi-matte double weight paper for greater durability since they are intended for class use, and because mapping can be done and subsequently erased from semi-matte paper. For display purposes

* Index to Aerial and Ground Photographic Illustrations of Geologic and Topographic Features throughout the World. Headquarters Army Air Forces, September 30, 1946; and Supplement 1, 1949.

† Interim Catalogue of the Geological Survey Collections of Outstanding Air Photographs by Lang, Bostock, and Fortier. Paper 47-26, 1947.

glossy prints are preferable. The contrast of paper used varies greatly. For display and use without stereoscopic aid, fairly contrasty paper is preferred, but this is not especially advantageous when the photos are studied with the stereoscope.

Although index sheets have been ordered especially as an aid in selecting individual photos, there are areas in which the index sheets are of fairly large scale, and the features shown are better studied on them than on individual photographs. This proves to be especially true in the folded Appalachian Mountains of Pennsylvania, where an individual photo may show such a small part of one of the large folds that it is difficult to see it in its proper relations.

Index sheets including from a few photographs such as 6 to as many as 300 or more have been received. The number of index sheets necessary to cover a county of average size for the eastern United States varies from 1 to as many as 30. Each extreme is less satisfactory than intermediate scales where 4 to 6 sheets cover an average sized county. Then the individual photos on the index sheet are large enough to be plainly seen and the area covered is sufficiently large to show features desired. An example of very large scale is in Production and Marketing Administration index sheets of Dauphin County, Pennsylvania, where an index sheet may not adequately cover even a single Susquehanna River water gap.

The clearer atmosphere of the Rocky Mountain, Colorado Plateau and great basin areas generally gives a more satisfactory display of geologic structure. Topographic maps of the Milheim, Loysville, New Bloomfield, and Williamsport quadrangles, Pennsylvania, afford some of the finest illustrations of Appalachian folding, but agricultural patterns, fence lines and forest cover present confusing distractions in many photographs of the areas. Photographs of areas in the Big Horn, Wind River and Hanna basins, Wyoming, afford quite superior illustrations of folded and faulted structure. In Sequatchie County, Tennessee, and other eastern forested areas, adjacent flight strips were made during winter and summer seasons. Details of structure can be followed much more readily on photographs made when deciduous trees were leafless.

OUTSTANDING AERIAL PHOTOGRAPHS

In the following comments on outstanding illustrations of various types of geologic features, the abbreviations are used as follows for sources from which photographs were obtained.

- AF Air Forces, Photographic Records and Services Division, Rm. 1D-420, Natl. Defense Bldg., Washington 25, D. C.
- C & GS Coast and Geodetic Survey, U. S. Department of Commerce, Washington 25, D. C.
- FS Forest Services, U. S. Department of Agriculture, Washington 25, D. C.
- GS-D Geological Survey, U. S. Department of the Interior, New Federal Center, Topographic Branch, Denver, Colorado
- GS-W Geological Survey, U. S. Department of the Interior, Washington 25, D. C.
- PMA-SL Production and Marketing Administration, U. S. Department of Agriculture, Western Photo Laboratory, 167 W. Second St. S., Salt Lake City 2, Utah
- PMA-W Production and Marketing Administration, U. S. Department of Agriculture, Washington 25, D. C.
- SCS Soil Conservation Service, U. S. Department of Agriculture, Washington 25, D. C.
- TVA Tennessee Valley Authority, Map and Survey Branch, Chattanooga, Tennessee

Following a symbol for the agency are the code letters, if any; then the flight or roll number, if any; then the particular photograph or series of photographs.

Thus the sand dune photos near Moses Lake, Washington, mentioned above are designated—PMA-SL: AAR-24A-62 to 24A-65. This indicates that the photographs may be secured from the Photo Laboratory of the Production and Marketing Administration in Salt Lake City, the code letters are AAR and the four photos are negative numbers 62 through 65 of roll or flight 24A. Photo index sheets are variously designated. An example would be—PMA-W: Ocean Co., N.J., Sheet 11 of 11, for an Atlantic coastal area showing Barnegat inlet and tidal delta on the New Jersey coast. Nearly all of the photographs and index sheets mentioned were not subject to military classification when secured, but this is subject to fairly frequent change. For vertical aerial photographs at least two are generally listed so as to permit stereoscopic study.

Sand Dune Areas. Sand dune areas are rarely similar in dune pattern. In addition to the Moses Lake quadrangle mentioned above, a similar diversity is seen in the White Sands National Monument, Otero County, New Mexico (SCS: CTF-1-142 and 1-143) and the Great Sand Dunes National Monument, Saguache and Alamosa Counties, Colorado (FS:CL-36-20 to 36-29). (There is no photo 36-24.) Coastal Sand dunes along Lake Michigan in Indiana Dunes State Park, Porter County, Indiana, show active and stabilized blow out dunes (PMA-W: BFP-5-3 and 5-4). A consistent pattern of elongate seif dunes parallel to wind direction is in Logan County, Nebraska (PMA-W: Logan Co., Nebraska sheet 4 of 4).

Solution Features. Sink hole areas in Kentucky show the myriads of small sinks of the Pennyroyal plateau in the Mammoth Cave area (PMA-W: A10-48-36 and 48-37). The larger and deeper sinks and solution valleys north of this are partially obscured by cultivation patterns and forest growth. Lake filled sinks of the Florida peninsula are found near Ft. Myers, Lee County (PMA-W: DCT-IC-65 to IC-68) and in the Everglades. Mountainous karst topography is found in Kwantung province, China (AF: 1893449 to 1893950).

Glaciers and Glaciation. Existing glaciers in the United States are well displayed in Mt. Shasta, California (FS: DDD-69-9 and 69-10) and no doubt in Mt. Rainier, of which photos have not yet been secured. Larger existing Alaskan glaciers are plentifully represented in photography by the Geological Survey. Photos (GS-D: SEA-95-95 to 95-100) are coastal glaciers in fiords and valley glaciers tributary to the great Malaspina glacier where photographed by the Air Forces (AF: 1803790 to 1803792). Some of the best cirques, horns, arêtes, and other erosional forms (FS: DDD-24-43 and 24-44) and lateral moraines (FS: DDD-24-77 to 24-80) of extinct valley glaciers of the high Sierra are in the Mt. Lyell quadrangle, Madera, Mariposa and Mono Counties, California. Other excellent examples of mountain glacial sculpture are in the Wind River Mountains, Wyoming (SCS: 0-106 to 0-112). Photographs have not yet been secured for Glacier National Park, Montana.

Moraines, drumlins, kames, eskers, pitted outwash and other land forms of continental glaciation, because of their lesser relief are not as spectacular as some other land forms, but mottled soil color patterns may permit recognition of morainic belts in the central states even where their relief is only 20 or 30 feet. Younger moraines with kettle hole lakes and associated outwash plains are well displayed near Dunseith, Rolette County, North Dakota (PMA-SL: BAG-15-13 to 15-20). The lakes have partially filled with marshy vegetation. Mottled soils marking morainic belts from which lakes and marshes have disappeared are well displayed in Livingston and other Illinois counties (SCS:

AS-1-37 to 1-39). Drumlins can be clearly recognized especially under the stereoscope but cultivation patterns on their slopes may distract attention from them. Good examples are near Fond du Lac, Wisconsin (PMA-W: XF-1B-109 to 1B-110).

Pitted outwash is present on Cape Cod, Massachusetts (GS-W: GS-F-4-206 and 4-207). Striking examples of eskers have not been acquired but some of the long Maine eskers should show up clearly. Canadian eskers listed as outstanding from the collection of the Geological Survey of Canada include (GSC-99122 and GSC-99119) both trimetrogon photos.

The contrast in age of till plains based upon the extent of dissection and the destruction of lakes and marshes is well illustrated by index sheets the Mankato (Late Wisconsin) drift sheet in Ottertail County, Minnesota (PMA-W; Ottertail County, Minnesota, sheet 3 of 4) the Tazewell (early Wisconsin) by LaSalle County, Illinois (PMA-W; LaSalle County, Illinois, sheet 2 of 5); the Illinoian drift plain by Brown County, Illinois (PMA-W; Brown County, Illinois, sheets 4 and 5 of 9); and the Kansan drift plain by Marion County, Iowa (PMA-W; Marion County, Iowa, sheet 1 of 1).

Coastal Features. Coastal features are superbly displayed on aerial photographs and they have the advantage over maps in that turbidity currents, wave refraction, rip currents, depth variation and subaqueous patterns of sand and mud distribution can be clearly observed. Splendid coastal photography in the University of Illinois collection is found in Franklin and Gulf Counties, western Florida; Lee and Dade Counties, southern Florida; Beaufort County, South Carolina; Ocean and Atlantic Counties, New Jersey; and Cape Cod, Massachusetts, all with low depositional shores; and Santa Rosa, Santa Cruz and San Miguel Islands, Santa Barbara County, and the Point Reyes quadrangle, Marion County, California afford excellent examples of coastal erosion forms. Among the depositional features striking tidal deltas of several types are in Lee County, Florida (PMA-W: DCT-2C-117 to 2C-119), and Barnegat Bay, New Jersey (PMA-W: Ocean County, New Jersey, sheet 11 of 11) prograding beach ridges in St. Vincent Island near Apalachicola, Florida (GS-W: GS-AB-1-135 and 1-136). A turbidity current entering the Gulf of Mexico through Indian Pass from Apalachicola Bay is in the same vicinity (GS-W: GS-AB-1-133 and 1-134).

Sandy beaches in coves are in Washington County, Maine (C & GS: 20-ME-C-977 and C-998). A fine spit is St. Joseph Spit, western Florida (GS-W: GS-AB-1-124 and 1-125.) Subaqueous sand ridges and channels are in a bay near Cape San Blas, western Florida (GS-W: GS-AB-1-130). A tombolo is Morro Rock, San Luis Obispo County, California (AF: 160 and 161). These photos, without code number, were secured from the PMA at Salt Lake City. Beach cusps are conspicuous on Santa Cruz Island, California (PMA-SL: BTM-312-47 and 312-48). A tombolo in process of formation but still in the subaqueous stage is in Lee County, Florida (PMA-W: DCT-2C-146 to 2C-148).

Wave refraction is illustrated in various photos in the Channel Islands off Santa Barbara, especially on Santa Rosa Island (PMA-W: BEI-3-37 and 3-38). Estuaries of the eastern shore of Chesapeake Bay are well shown by index sheets (SCS: Kent County, Maryland and vicinity, sheet 1 of 1). Abandoned shore lines of the ocean commonly show well, and coastal terraces may be seen on Santa Rosa Island, California (PMA-SL: BTM-313-36 and 313-37). Several abandoned shore lines of Lake Bonneville are prominent north of Salt Lake City, Utah (PMA-SL: AAL-1B-162 to 1B-166).

Landslides and Related Features. The Jackson Hole region, Wyoming, affords numerous illustrations of features resulting from mass movement. Of these the Gros Ventre slide is best known (AF: 160 DPU-4M-726-98V-147 to 98V-149). In the same region there are rock streams (AF: 160 DPU-47-726-100V-106 and 100V-107) and mud flows (FS: COC-5A-173 and 5A-174). Talus slopes merge into fan heads near Death Valley, California (GS-W: GS-IF, 4–92 to 4-94) throughout the basin ranges.

Features Resulting from Stream Activity. Features of running water origin are to be found almost everywhere and are clearly displayed on aerial photographs. The erosion cycle in all its stages both for individual valleys and for regions has numerous fine illustrations. The dissection of upland plains with headward and downward cutting is almost diagrammatic in table lands near the South Dakota badlands (PMA-W: BOI-186-30 to 186-34) and with higher relief in the Mesa Verde National Park, Colorado (SCS: DZ744 and 745). Canyons of Green and Colorado Rivers near their junction in Utah also exhibit entrenched meanders (SCS: COG-1-75 to 1-77) and these are seen even more strikingly in San Juan Canyon near and including the famous Goose Necks near Mexican Hat, Utah (SCS: DZ-77 and 78; DZ-345 to 347 and (no code letters) 4153 to 4155).

Late youthful dissection of a plain is displayed north of North Platte River in Goshen County, Wyoming (PMA-SL: 7-40 to 7-42). In more humid regions there are young valleys dissecting the Cumberland Plateau in Tennessee (PMA-W: BSR-39-134 to 39-137). Mature valleys with flood plains, meanders and ox bows are illustrated by Milk River in Valley County, Montana (PMA-SL) and Big Horn River near Thermopolis, Wyoming (PMA-SL: 59-3145 to 59-3147) and there are many other fine examples. Braided channels are, of course, shown by the North Platte River in Morrill County, Nebraska (PMA-W: CBA 8-59 to 8-54).

Rugged topography with early mature erosion is found throughout the Appalachian plateau province, a representative area being in southern West Virginia (SCS: southern West Virginia, sheet 36 of 41). In the semi-arid west, maturity is splendidly displayed in the White River plateau near the Colorado-Utah line (SCS: ALJ-2970 and 2971; and ALJ-3010 to 3020). Late mature erosion is found in the Green River Basin, Uintah County, Wyoming (PMA-SL: CVT-5B-21 to 5B-23).

Meander shifting of broad alluvial plains is shown throughout the Mississippi alluvial plain in Tallahatchie and surrounding counties, Mississippi (PMA-W: Tallahatchie County, Mississippi, sheet 4 of 4), and an unusually fine oblique photo illustrating this feature is in Alaska (AF: 1803803 and 1803804). Alluvial fans are plentiful around the borders of faulted western ranges, as the Lost River Range, near Mackay, Idaho (PMA-SL: CVP-4B-51 to 4B-55 and CVQ-2B-39 to 2B-61) and Death Valley, California (GS-W: GS-IF, 1-1 to 1-5 and 4-92 to 4-95) and in Jackson Hole, Wyoming (AF: 16 DPU-4M-726-96V-30 to 96V-32 and 96V-134 and 96V-135) and aerial photographs display finely their pattern of growth, the merging of individual fans into piedmont fan systems, dissection of fans and growth of second cycle and even third cycle fans. Small deltas are illustrated on the south side of Cape Cod, Massachusetts (GS-W: GS-F-7-83 to 7-85) and in New Guinea (AF: 1803997 and 1803998) and partially exposed deltas in the Salton Sea area, California (PMA-SL: ABN-3-81 and 3-82). A somewhat larger delta is formed by Flathead River, Montana as it enters Flat Head Lake (GS-D: GS-CJ-15-18 to 15-60).

Stream piracy at the northern escarpment of the Mesa Verde, Colorado, has resulted in the beheading of numerous older consequent valleys draining south down the dip slope (SCS: DZ-688 to 690 and 714 to 716). Dendritic drainage pattern is seen in many areas, especially in Bledsoe County, Tennessee (PMA-W: BSR-39-181 to 39-184) and in Honshu Island, Japan (AF: 1803967 to 1803969). Parallel drainage is due to several causes. In many areas it is a trellis pattern following the strata of tilted weak layers as in the Pawpaw quadrangle, West Virginia (GS-W: GS-DS-4-51 to 4-53), but elsewhere it is controlled by joint systems, as in Zion Canyon Utah (SCS: BPI-41-196 to 41-198), by prevailing wind direction, as in western South Dakota (PMA-W: BOI-136-136 to 136–138), or to crevasses systems in a lobe of the Pleistocene glacier, as in various areas in western Illinois. The water gaps of the Susquehanna River near Harrisburg, Pennsylvania (PMA-W: AHE-59-59 and 59-60 and 58-105 to 58–107) are among many good examples of this feature. Alluvial terraces are well displayed along Green River near the Utah-Colorado line (SCS: ALJ-5241 to 5243).

Volcanic Features. Volcanic features are commonly striking. Cinder cones and associated lava flows are clearly shown in the San Francisco Mountain region, Arizona (SCS: Little Colorado project, quadrangle no. 4 (Ariz. 142) and photographs BT-1994 to 1996 and BT-1950 to 1953). A remarkable association of lava flows on a faulted folded and truncated surface of Paleozoic rocks with a cinder cone and several dikes on the immediate vicinity is found on the western side of Elephant Butte Reservior, New Mexico (SCS: Rio Grande Valley Project 8606 to 8608). Lava flows on the slopes of Mt. Shasta, California, show flow line patterns (FS: DDD-68-37 to 68-40). Ship Rock, New Mexico, a volcanic plug with radiating dikes has often been used as an illustration (SCS: Navajo area, 6019 to 6021).

The Devil's Tower, Wyoming, has been called both a volcanic neck and a laccolith (PMA-SL: 32-96 and 32-97). Calderas are illustrated on Hokkaido Island, in Japan (AF: 1803986 to 1803988) and several remarkably deep craters with low rims in Sudan, Africa (AF: 1803640 to 1803643). Dike ridges are prominent around the Spanish Peaks, Colorado and include intersecting dikes (FS: CL-22-31 to 22-36). A perfect laccolithic dome in which the core of igneous rock is not yet exposed is Green Mountain, near Sundance, Wyoming (PMA-SL: BBU-29-77 to 29-79). The partially uncovered laccolith, Inyankara Mountain is in the same vicinity (PMA-SL: BBU-26-17 to 26-19). Successive sheets of basaltic lava now extensively eroded are found in the Grand Coulee region, Washington (PMA-SL: AAR-9A-33 and 9A-34).

Structural Features. Rock benches or terraces in horizontal rocks with erosion remnants are found near the junction of Green and Colorado Rivers in San Juan County, Utah (SCS: COG-2-38 and 2-39). Joint systems are among the more spectacular features in semi-arid areas. The most extensive display thus far encountered is in the Permian Cedar Mesa sandstone in San Juan County, Utah (SCS: COG-1-65 to 1-70 and 1-107 to 1-114), but the Navajo sandstone of the San Rafael Swell, Emery County, Utah (SCS: BPM-15-139 and 15-140) is equally striking. One of the best displayed regional escarpments is that of the Book Cliffs northwest of Green River, Utah (SCS: ALJ-11756 to 11758). A series of minor escarpments or cuestas is found in the Bridger Basin, Uintah County, Wyoming (PMA-SL: CVT-2B-52 to 2B-54).

One of the finest groups for photographic quality thus far encountered is in the southern Big Horn basin, Wyoming (PMA-SL: Hot Springs County, Wyoming, sheets 3 and 4 of 4). Among the features finely displayed in this area are cuestas (PMA-SL: CWH-2B-40 to 2B-42) dip and strike of tilted sedimentary rocks (PMA-SL: CWH-2B-110 to 2B-113 and 2B-130 to 2B-132) and a pitching asymmetrical anticline (PMA-SL: CWH-2B-133 to 2B-136 and 2B-181 to 2B-184). An elongate doubly pitching anticline, Wills Mountain, Bedford County, Pennsylvania, is asymmetrical, partly breached and shows three water gaps on its steeper flank (PMA-W: Bedford County, Pennsylvania, Sheets 3, 4, 8, 9 and 10 of 21). A doubly pitching canoe shaped syncline is in the Needmore quadrangle, Pennsylvania (PMA-W: Fulton County, Pennsylvania, sheets 5, 8, 9 and 10 of 10). A perfectly symmetrical dome in French West Africa is shown in oblique photographs (AF: 1803651 to 1803653), and round basins are seen in a desert area of Morocco (AF: 1803715). A small dome in the Wind River basin, Wyoming, is entirely included in a single photograph (GS-D: GS-1E-5-106 to 5-109).

Complex pitching folds in Morocco, Africa are shown by oblique photographs (AF: 1803673 to 1803676). There are many other fine available photographs of tilted and folded rocks. Faceted spurs of great fault scarps are found in the Wasatch Mountain front near Brigham City, Utah (FS: HA-1-32 to 1-34), and on the west slope of the Sangre de Cristo Mountains in Saguache County, Colorado (FS: CL-25-76 to 25-78). Offset of stream courses by three parallel high angle faults is seen in the San Rafael Swell, Emery County, Utah (SCS: BPM-15-141 and 15-142). The Uinta thrust fault in which massive pre Cambrian quartzites with coarse textured drainage are thrust north over Paleozoic and Mesozoic folded strata with fine textured drainage extends along the northern side of the Uinta Mountains, Utah (SCS: ALJ-5044 to 5047).

An unconformity of late Paleozoic sediments on pre Cambrian granite is on the west slope of the Laramie Range, Wyoming (FS: CID (12-11 to 12-13). Tertiary lavas rest unconformably on tilted and faulted Paleozoic rocks near Elephant Butte Reservoir, New Mexico (SCS: Rio Grande Valley area, 8254 to 8256).

Lineations. Parallel arrangements of geologic features are generally more evident in aerial photographs than on the ground. The cause for such arrangements is sometimes, but not always evident. Joint systems and their control on drainage patterns have been mentioned above, as have seif dune ridges, trellis drainage, and stream directions controlled by prevailing wind direction. Prograding sand ridges along a shore may produce lineations which may extend some distance inland from the present shore, as in northern South Carolina where photos show beach ridges with one trend and the Carolina Bays with another (PMA-W: Horry County, South Carolina, sheet 5 of 5). Pimple mounds probably due to wind action lie on basaltic lavas in the Grand Coulee region, Washington (PMA-SL: AAR-9A-53 to 9A-55).

A remarkable alignment exists in minor stream valleys throughout western Illinois which is parallel to the direction of glacial advance and may indicate that stream systems began along radial crevass systems in the ice. Lineations due to drumlins have been mentioned and those due to ice scour may be seen near Ely in northern Minnesota (FS: FX-3-8 and 3-9). A remarkable lineation of elongate oval depressed basins is seen almost throughout the Everglades in Dade County, Florida (SCS: Everglades area, Sheets 27, 28, 29, 32, 33, 34 and 36). This may be due to solution of reef limestones but is more likely related to current action from the Gulf Stream currents sweeping around the end of the Florida peninsula.

SUMMARY

The foregoing is a very sketchy survey of outstanding photographs of geologic phenomena, largely from the University of Illinois collection. In each example a fuller description of the phenomenon could have been given, but this would have lengthened the article unduly.