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MAPPING QUATERNARY LANDFORMS AND DEPOSITS IN THE MIDWEST AND GREAT PLAINS BY MEANS OF ERTS-1 MULTISPECTRAL IMAGERY[1]

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Abstract

ERTS-1 multispectral images are proving effective for differentiating many kinds of Quaternary surficial deposits and landforms units in Illinois, Iowa, Missouri, Kansas, Nebraska, and South Dakota. Examples of features that have been distinguished are: the more prominent end moraines of the last glaciation; certain possible "palimpsests" of older moraines mantled by younger deposits; various abandoned river valleys, including suspected ones deeply filled by deposits; river terraces; and some known faults and a few previously unmapped lineaments that may be faults. The ERTS images are being used for systematic mapping of Quaternary landforms and deposits in about 20 potential study areas (mostly 1° x 2° in size) within the project area. Some study areas, already well mapped, provide checks on the reliability of mapping from the images. For other study areas, previously mapped only partly or not at all, our maps will be the first comprehensive, synoptic ones, and should be useful for regional land-use planning and ground-water, engineering-geology, and other environmental applications.

This project is testing the applicability of ERTS-1 images for identifying and mapping Quaternary surficial deposits and landforms in six Great Plains-Midwest States - Illinois, Iowa, Missouri, Kansas, Nebraska, and South Dakota. Among the features we are looking for are end moraines of the last glaciation, terrace sequences along the main rivers, and middle or early Pleistocene glacial moraines and valleys that have been buried beneath younger glacial drift, loess, or eolian sand.

[1]Publication authorized by the Director, U.S. Geological Survey.

The geological surveys of the six States are collaborating on the project and the State geologists are coinvestigators. Twenty-four potential study areas, mostly $1^\circ \times 2^\circ$ in size and covering a total of 155,000 square miles, have been selected for intensive study (Fig. 1). Each study area is of current interest to the respective State's geological survey. Those areas that are already well mapped will provide checks on the reliability of our mapping from the ERTS images. For other study areas, previously mapped only partly or not at all, ours will be the first, comprehensive maps; they should be useful for regional land-use planning and for ground-water and other environmental applications.

The investigation of each area progresses through six phases. Phase 1 consists of preliminary mapping of geologic and geomorphic features using only ERTS imagery. Higher phases involve published and unpublished ground truth data, and,, from repetitive ERTS imagery, additional data revealed by changes in time-variant phenomena such as vegetative cover, soil-moisture conditions, plowing of croplands, and snow cover. Phase 6 is the delineation of the new information detected from the RTS imagery.

To date, we have received only 70 mm positive transparencies and some 70 mm negatives that are mostly too dense to produce satisfactory enlargements wi:h the equipment we have. We examine the positive transparencies under 8X to 10X magnification, and in some cases with an I^2S Mini-Addcol additive color viewer. In order to provide a photographic base for mapping

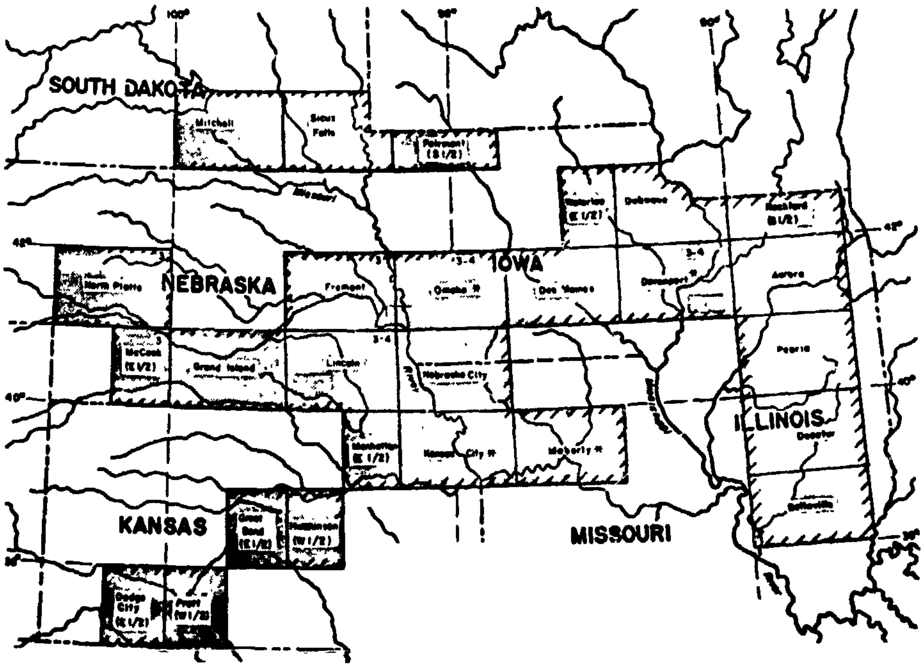


Fig. 1. Map showing the potential study areas in the Great Plains-Midwest region.

geologic-terrain features, we originally prepared <u>negative</u> enlargement prints from the 70 mm positives, at scales ranging from 1:1,000,000 to 1:250,000. Now, however, we are using internegatives prepared from the 70 mm positives to make enlarged <u>positive</u> prints. We believe that it would be more efficient and productive if we use 9" x 9" positive transparencies under a zoom transferscope and mapped our interpretations directly onto our base maps, but to date we have received very few of the large transparencies.

Problems that have hampered this investigation are the ubiquitous vegetative cover during the growing season throughout the Great Plains-Midwest, the exceptionally rainy and cloudy summer and fall, and attendant commonly poor atmospheric conditions. During the summer growing season, crops and natural foliage in the pastures and woodlands greatly obscure information about the geology, soils and even the smaller topographic features. In the summer images, the "red" MSS band 5 was the most useful for interpreting geologic-terrain units. In the fall images, the infrared bands have become more important because the total infrared response from crops and natural vegetation has decreased. Spring imagery should yield the most information about soils, surficial deposits and landforms

We are quite pleased with the potential afforded by ERTS images for differentiating and mapping geologic-terrain units at scales of 1:250,000 and smaller. Resolution and detectibility are surprisingly good. Rural "section line" roads, typically 60 to 80 feet wide (including roadbed, shoulder, ditches, and backslope) generally can be identified, thus enabling precise location of features. We find that the main landform associations and larger landforms generally are quite distinct on the better ERTS images, and commonly the gross associations of Quaternary surficial deposits also can be differentiated. It is appropriate to point out that for the interpretation of geologic-terrain features from small-scale images like these, rarely are there "unique signals"; instead, we must deal with differences that commonly involve small, subtle changes in several components of an image, for example, in tone, texture, pattern, hue, and chroma. We interpret landform types by analyzing stream dissection and drainage patterns, stream-divide relations, and land-use patterns. Interpretation of surficial materials is more difficult than that of landforms and generally involves secondary and tertiary levels of inference. Thus, a considerable input of "ground truth" is essential to control the inferences if a reliable map is to be produced. The ground truth may come from published geologic maps, unpublished maps and file data, subsurface data (drill-hole logs), and from field studies by ourselves and our collaborators in the State geological survey.

Among the features that have been identified are the major outwash channels and moraines formed during the last galciation, such as the Bloomington and Shelbyville moraine systems in Illinois and the Bemis and Altamont moraine systems in Iowa and South Dakota. Much less evident are moraines of earlier glaciations. These invariably are severely eroded and buried beneath variable thicknesses of loess and other sediments. Synoptic analysis of drainage and stream-divide patterns and degrees of stream dissection is helpful in detecting anomalies that may signal buried moraines. This analysis is greatly facilitated by the comprehensive mega-views provided by the ERTS images. From analysis of drainage and stream-divide patterns in Nebraska, Kansas, Iowa, and Missouri, we have been able to identify several pre-Wisconsin moraine systems that already are fairly well known, mainly from borehole data. Also, several other similar anomalies that have been found in these States may indicate previously unrecognized pre-Wisconsin moraine systems.

Similar analysis has proved useful for detecting abandoned river valleys, especially ancient filled ones which are hard to identify. Several known filled valleys and a few possible ones have been found.

Figure 2 is typical of the preliminary maps prepared during the earlier phases of our program of investigations. The map, a composite of two of our study areas (the North Platte 1° x 2° quadrangle and the eastern half of the McCook quadrangle), is representative of both the Sand Hills and the High Plains of western Nebraska. Although coverage by satisfactory ERTS images still is incomplete, and limited mostly to images obtained during the growing season, vegetative cover in this semiarid region is less of an impediment than in the more humid region to the east. Analysis of both land-use patterns and stream-dissection/stream-divide patterns has enabled mapping the major geologic-terrain units. On the best image of the Sand Hills portion, the larger dunes and interdune depressions can be distinguished clearly. The infrared bands afford a synoptic register of the water-level status of the myriad ponds and marshes in this area, and thereby an up-to-date inventory of ground water conditions. Hydrologists lately have become concerned about possible depletion of ground-water by overpumping in some parts of the Sand Hills.

Figure 3 is a reduction and generalization of a preliminary map of the Lincoln, Nebraska, 1° x 2° study area. This area is typical of the transition zone between the unglaciated eastern Great Plains and the Central Plains that were glaciated during the middle and early Pleistocene. This map shows not only the major classes of geologic-terrain units that can be differentiated from the ERTS images but also several of the rather obscure buried features that we are trying to find. The trend-lines of three ancient moraine systmes are revealed by anomalous drainage and stream-divide relations. The moraines, of Kansan and perhaps greater age, were much eroded before being covered by loess; thus, they are not very obvious. An aberrant stream pattern near Lincoln also reveals a buried valley. These features have been substantiated by surface and drill-hole data collected by the Nebraska Geological Survey.

A 10,000 square-mile area extending from Des Moines to 30 miles west of Omaha has received the most study to date (Fig. 4). Only a few of the more significant features are shown. The most prominent boundary in the north-eastern part is that between the area covered by ice as recently as 14,000 to 13,000 years ago (the Des Moines glacial lobe) and the older landscape in

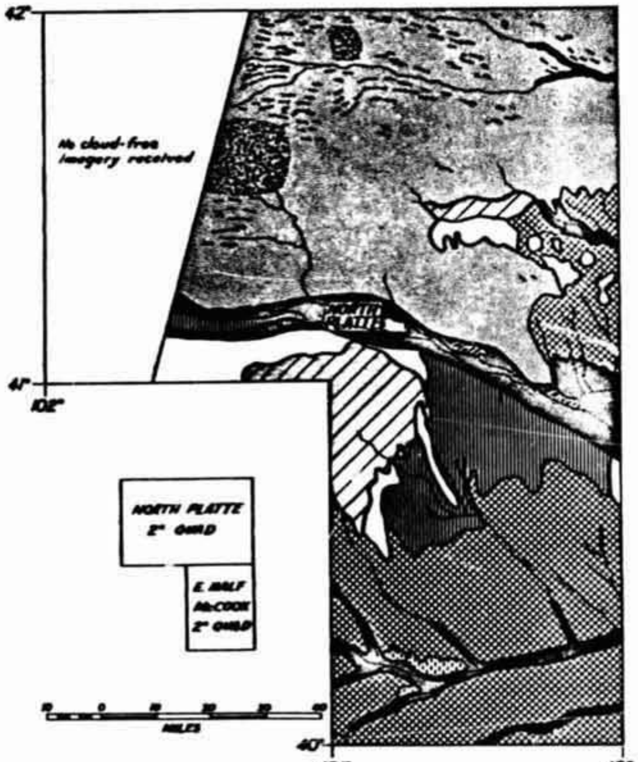
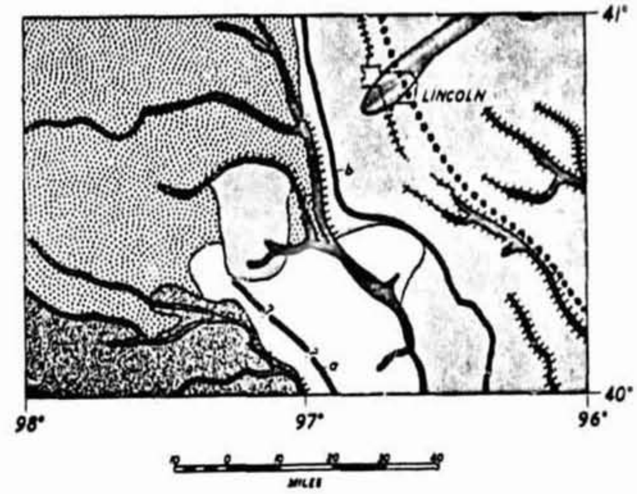


Fig. 2

PRELIMINARY MAP OF THE NORTH PLATTE AND EASTERN MC COOK, NEBRASKA, STUDY AREAS

EXPLANATION

Map unit		Landform characteristics	Surficial geologic materials
		Valley lowlands--flood plains and lower alluvial terraces	Alluvium of late Quaternary (Wisconsin and Holocene) age
	Sand Hills units	Higher, most extensive and continuous sand dunes. Local relief commonly 100 to 250 ft. Transverse and longitudinal dunes alternate with narrow interdune lowlands that have ponds and marshes locally; very few streams. Heavy dashed lines indicate trends of the larger elongate dunes. Heavy stipple shows areas with many active sand blowouts.	Eolian sand, 50 to more than 250 ft thick, over middle Pleistocene alluvium, loess, and other deposits.
	Sand Hills units	Lower sand dunes and sand plains with isolated dunes; local relief generally less than 75 ft; very few streams.	Eolian sand, 5 to rarely more than 75 ft thick, over middle Pleistocene alluvium, loess, and other deposits.
		Plains, nearly level, with local relief generally less than 50 ft, rarely 100 ft; few, widely spaced streams.	Loess and local eolian sand over middle Pleistocene alluvium and loess.
		Moderately dissected plains (local relief generally less than 200 ft), moderately wide to narrow, relatively level interstream uplands; stream valleys moderately spaced.	Uplands have thick loess mantle of late Quaternary age over middle Pleistocene alluvium and loess, and in the S half of the E1/2 McCook quadrangle, over bedrock (mainly Ogallala Formation).
		Moderately dissected plain (local relief generally less than 100 ft).	Uplands have loess mantle of late Quaternary age over possibly either middle Pleistocene alluvium or bedrock.
		Highly dissected plains (local relief commonly about 200 ft), with closely spaced valleys and narrow interstream divides.	Uplands have thin loess mantle of late Quaternary age over middle Pleistocene alluvium and loess.



EXPLANATION

Compiled from ERTS-1 images 1022-16384-5; 1095-16451-5, 7; 1076-16391-5, 7

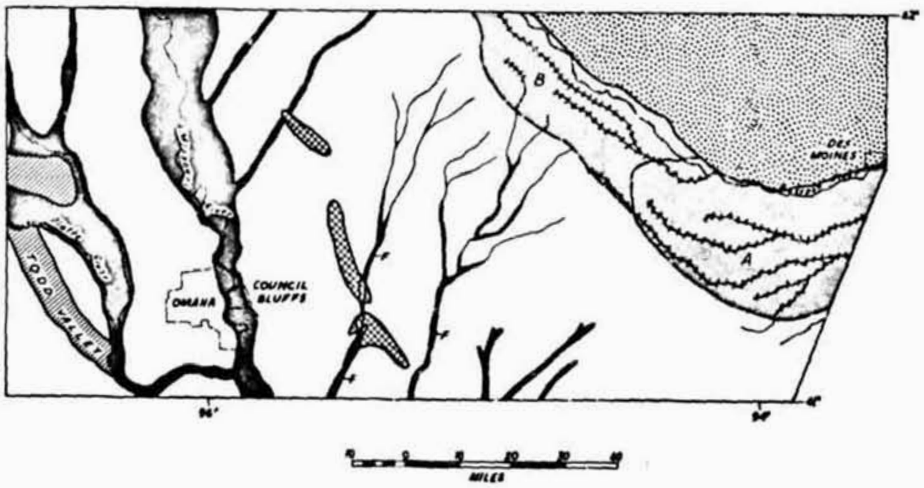
Map unit	Landform characteristics	Surficial geologic materials
	Plains with widely spaced streams and wide, nearly level interstream uplands. Main streams are entrenched generally less than 100 ft.	Uplands have thick loess mantle of late Quaternary age, overlying middle and early Pleistocene alluvium and loess, and till locally in eastern portion.
	Moderately dissected plains. Moderately wide to narrow, relatively level interstream uplands, stream valleys moderately spaced. Main streams are entrenched 100 to about 200 ft.	
	Moderately dissected plains like above.	Uplands have thin to thick loess mantle of late Quaternary age, over till, alluvium, and other deposits of middle and early Pleistocene age.
	Intricately dissected plains with closely spaced valleys and narrow interstream uplands. Main streams are entrenched 100 to rarely more than 200 ft.	
	Valley lowlands distinguishable on the ERTS images: flood plains and lower alluvial terraces, hachured where alignment possibly was controlled by moraines of middle or early Pleistocene age.	Alluvium and local loess of late Quaternary (Wisconsinan and Holocene) age.
	Ancient (middle Pleistocene) valley	

Streams without lowlands distinguishable on ERTS images, whose alignment possibly was controlled by moraines of middle or early Pleistocene age.

Drainage divide controlled by known morainic system of middle Pleistocene ("Kansan") age. a = moraine of the Nickerson Till; b = moraine of the Cedar Bluffs Till.

Trend-line of drainage anomaly, possibly due to moraine system of middle or early Pleistocene age.

Fig. 3. Preliminary map of the Lincoln, Nebraska, study area



EXPLANATION

Map unit	Landform characteristics	Surficial geologic materials
	Valley lowlands. Flood plains and lower terraces. "F" denotes inundated zones along the East and West Nishnabotna Rivers, detected from ERTS imagery.	Alluvium of late Quaternary (Wisconsin and Holocene) age.
	..ains, moderately to intricately dissected.	Uplands are mantled with loess of late Quaternary age, over till and other deposits of middle and early Quaternary age.
	Intermediate terrace of the Platte River, and Todd Valley, an abandoned channel of the Platte River.	Alluvium of Wisconsin age.
	Moraines (Bemis end moraine system) and till plain of the Des Moines glacial lobe.	Till of late Wisconsin (Cary/late Woodfordian) age, locally [illegible] er older Pleistocene deposits.
	"Tonally anomalous" area with arcuate entrenched drainage paralleling the Bemis moraine system. Area A is delineated from image 1003-16334-5; area B is a possible extension, from image 1078-16384-7.	Uplands are mantled with rarely more than 20 ft of late Quaternary loess, over till of middle and possibly early Pleistocene age.
	Anomalously dark areas (with low infrared reflectance) on image 1003-16334-7.	Like unit 2. Significance of the infrared anomalies is uncertain.

Streams whose alignment possibly was controlled by moraines of middle or early Pleistocene age.

Fig. 4. Preliminary map of the Omaha and parts of the Des Moines and Fremont study areas, Nebraska and Iowa

the south that was glaciated in middle Pleistocene time and is now deeply dissected by streams. This boundary is fairly obvious (from land-use patterns) on the "red" MSS band 5 in images taken during the growing season, but is indistinct on the infrared bands. On an October 7 frame, however, this boundary is best defined on infrared band 7.

Extending 15 to 24 miles south of this boundary is an interesting area to which we have given considerable attention. It is "tonally anomalous" (in photointerpretive terms) in that it has tone and texture more like the young glaciated terrain within the Des Moines lobe than like the older dissected Kansan till plain of southern Iowa. Moreover, both its overall plan and its stream pattern are arcuate, parallel with the outer edge of the Des Moines glacial lobe. This arcuate parallelism suggests that the streams may have been alined before their entrenchment by a set of previously unrecognized moraines of an ancient ancestor of the Des Moines lobe, at least Kansan in age, perhaps early Pleistocene. Supporting this hypothesis is evidence that the arcuate drainage pattern is not controlled by bedrock lithology or structure. The valleys cut across several structural trends and across the boundaries of formations having considerable difference in lithology and resistance to erosion. They also cross buried "preglacial" bedrock valley that is concordant with the bedrock structure.

This map also shows the zones inundated by a major flood, as mapped from the ERTS imagery. These zones are the "valley lowlands" designated by "F" in the south-central part of Figure 4. From September 11 through 13, the East Nishnabotna River, in southwestern Iowa, had a flood of probably greater than 50-year-recurrence-interval magnitude. The West Nishnabotna River also flooded, to somewhat lesser degree. The inundated zones show as clearly anomalous dark zones on the infrared bands (especially band 7) of ERTS images taken 6 and 7 days after the flood. The reduced infrared reflectance appears to result from excess soil moisture and plant stress. The Remote Sensing Laboratory of the Iowa Geological Survey, under the direction of James Taranik, mapped the inundated zones from multispectral and color-infrared aerial photographs taken 3 days after the flood. The inundation limits mapped from the airphotos agree well with those mapped from the ERTS images.

In conclusion, the ERTS multiband images have both limitations and certain strong advantages. Their chief limitation are their moderate degree of resolution-detectability and their very limited stereoscopic capability. Even where lateral variations in orbital tracks have resulted in considerable overlap between repetitive images of the same area, the high orbital altitude results in such limited parallax that small differences in relief cannot be seen.

Their chief advantage, in our opinion, is that they provide instantaneous mega-views of very large regions. Another important advantage is that they pinpoint the areas where field and/or subsurface studies are needed. Their multispectral and repetitive coverage is an additional strong asset.

These images, the first space images of the Great Plains and Midwest, already show great potential as important new research tools for synoptic geologic-terrain mapping and related studies. For small-scale mapping they are far superior to conventional aerial photographs and airphoto mosaics. The ERTS-1 images bring out relationships that never before were so evident. We must point out, however, that extracting some kinds of information, or detecting anomalies from the images of the Great Plains and Midwest is more difficult than in areas of higher relief, less vegetative cover, and less atmospheric haze. Owing to the small relief in this region, considerable study and repeated viewing of the images are required to detect anomalies that may indicate such less obvious features as buried valleys and moraines.