Screenings from the Soil Research Lab

IOWA ENGINEERING EXPERIMENT STATION
IOWA STATE UNIVERSITY of Science and Technology
AMES, IOWA

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CRUISING DOWN THE RIVERS

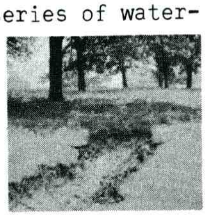
Overture: Water Music

All the world's a stage, which would be agreeable enough except for so much recurrent bad acting. Let us away from the discord and melodrama, to enjoy the prodigious scenery and set design. Design credits go to wind, water and ice, plus a few periodic pyrotechnics and minor ups-and-downs. Of these, water is the most vigorous sculptor, carving massive monuments and daubing widespread abstractions with the debris. Our subject today, rivers.

Biography of a stage hand

Rivers are confederated raindrops with only one goal: downhill. With such singleness of purpose their enthusiasm easily runs all over itself. Gay, impassioned youth cuts a hectic channel, and gullies form, enlarge and deepen into V-shaped valleys.

Downward cutting of young streams often involves upstream migrations of a series of waterfalls, or nickpoints. In addition to cutting downward, the streams cut headward so that gullies not only grow deeper, they grow longer. Gradually, fields and farms--goodbye.



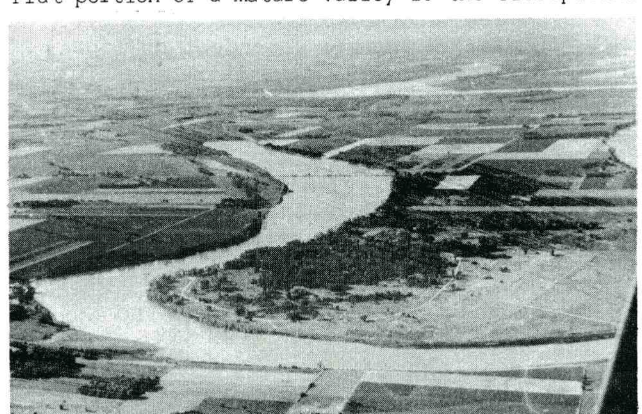
Eventually downward cutting by a given section of stream must stop or the water will run backwards and we will all be eaten by sharks. Downcutting is controlled by a base level, the ultimate base level being sea level. A stream can't cut its valley much below sea level unless it runs uphill.

Youthful valleys often get their start and are cut downward in a series of retreating nickpoints (arrows). Here nickpoints are chopping at easily eroded loess or silt soil, western Iowa.

To many Americans Niagara reenacts the incandescent thrill of falling in love, the romantic version of being sold down the river. Don't dash your head on the rocks.

In addition each river forms the base levels for its tributaries, and local base levels can be hard ledges of rock. A stream bed trimmed to a downstream base level approaches a condition known as graded, where on the overall it neither cuts nor fills, it just carries.

Mastery by a base level changes a river's personality and vigors; it can no longer cut downward so it cuts sideways, gradually expanding its valley at the waistline and changing the shape from a V to a ⊔ . This stage is aptly termed maturity, the middle-aged spread. The flat portion of a mature valley is the floodplain.



The Missouri: There today, here yesterday. The river cut off a meander and departed to the right background. Very common. For details and reasons, turn the page.

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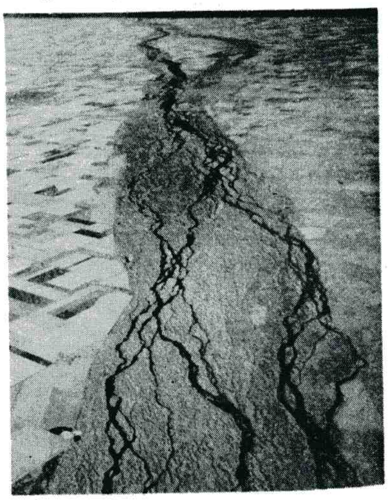
An overwhelming complication is that during the relatively recent continental cold spells much water was engaged in being glaciers. Therefore sea level was undecided, and the base level for all major rivers went up and down like a yo-yo. Every time it came up, river valleys filled with whatever was available, and the rivers got some floodplains. Whenever sea level went down, rivers were "rejuvenated;" they cut downward and left the old floodplains as terraces. Currently sea level is high and valleys are full, but there are a few terraces stuck along the edges.

BRAIDED RIVERS

Graded streams burdened with a manly load of sediment appear energetic enough, but they are easily triggered into relaxing and dropping their socks. The result is that the stream bed, like any other bed under the circumstances, becomes a bit of a clutter. Channels are continually plugging, dividing and recombining until the pattern reminds one of braiding self-taught by a three-year-old.



Platte means flat (Gr.), and describes the braided Platte River in Nebraska. Infra-red photo gives black sky and water, white fields and exceptional haze penetration. Compare with lower right, page 1.

Braided streams are particularly prominent in two environments--in dry regions, and in streams laden with debris from melting glaciers. A special case of braiding more dependent on local conditions is the alluvial fan, where youthful streams are so unexpectedly regimented into maturity they unload their souls and become beat, cool, and lazy. Resulting sloping fan-shaped deposits characteristically occur where streams run out onto plains, for example onto the floodplain of a mature stream valley.

A fan dances out of the hills and does an abbreviated cover-up. The contributing valley shows some sharp features of youth and is cutting a very nice V back into the Alaska Range.

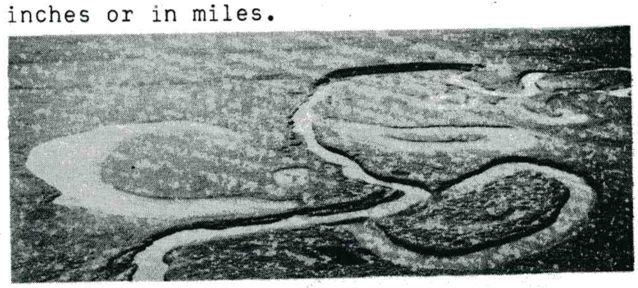
Flat, flat floodplain, an area of lateral planation by the Missouri River. Here the deposit is "backswamp" silt and clay, discussed on p. 4. Along the bluffs on top of the backswamp are a series of locally derived alluvial fans (arrows). Infra-red photo.

MEANDERING RIVERS

The other breed of mature streams is in the leisure class and still has enough energy for play. These streams are the glamour folk of the stage, sweeping about, winding and weaving a delicious musical fantasy complete with rhythm, symmetry, pattern, harmony, and dancing girls.

By meandering, a stream dissipates some of its mechanical energy as heat because of increased frictional drag and eddying. Furthermore meanders increase the channel length, decreasing the feet-per-mile gradient and hence stream velocity. Artificially straightened stream channels eventually meander again. Even the Gulf Stream meanders.

Once the fact of meanders is established in a stream, the loop curvature tends to adjust so energy loss is at a minimum. It is much like golfing for exercise, then riding all day on a golf cart. To minimize energy loss, average meander loop radii adjust to about two to three times the channel width, whether measured in inches or in miles.



Water flowing through a meander exerts some push against the outer bank, deepening the channel and making a catfish haven. (That's hill talk for heaven.) The water also tends to cut away the bank and deposit material on the opposite shore, with the net effect that the meander slowly migrates downstream. Most meander migration occurs during the late stages of high water, when the saturated and relaxed river bank is losing the support from buoyancy, and just sighs and slips in.

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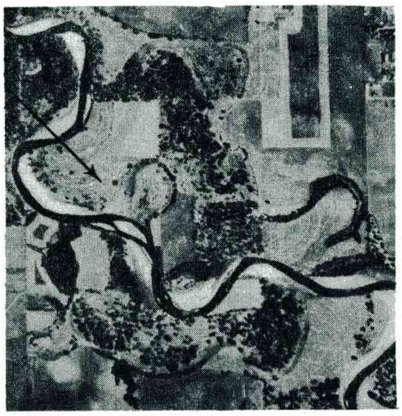
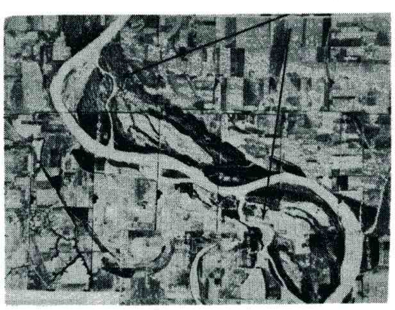
Point Bars

Lab experiments show that erosion from a river bank lends to sand deposition along the next convex bank downstream on the same side of the river. As meanders migrate they leave sandy point bars, hummocky deposits filling the areas within the meander loops. On airphotos the regular scarred pattern resembles finger prints. Sometimes the pattern is finger prints if your photos are not the best.



Point bars from the Iowa River. Scars indicate downstream migration of meanders (arrow). Latest deposits are white: older deposits are gray due to cover by 1 to 4 feet of clay, plus willows; oldest deposits are covered by trees and thicker clay. Other features: a chute, neck cutoffs, clay plugs.

A miscellaneous feature of some point bars is chutes--narrow shortcut channels across the toe of a meander. Chutes on the Mississippi were once used by scampering steamboats during high water, at some little risk of scraping the sides or running aground several miles from the river. Permanent chutes develop their own miniature meander pattern, and if a chute is so seditious as to capture the entire river it is called a chute cutoff.



Missouri River chutes (arrows) developing their own miniature meanders, loop radius being proportional to width of the stream. Location about 15 miles north of Omaha-Council Bluffs.

La guillotine

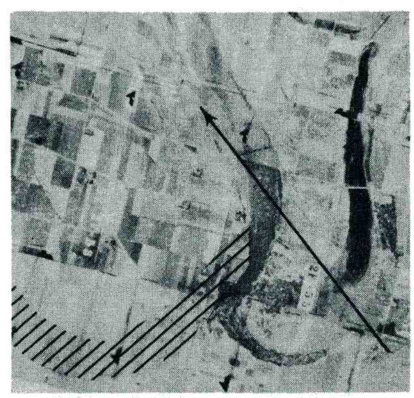
Model experiments with sand have shown that eroding meanders slowly snake their way downstream all at the same speed, like waves. Unfortunately life's environments are not so ideal, and meanders in nature don't all progress at the same speed. One may bump into an obstacle, giving the next one time to catch up. When this happens the tardy loop is cut off by a spectacular re-routing of the river over to the other side of the point bar. C'est un neck cutoff, le chop.

Neck cutoffs once created so many political embarassments by overnight reversing taxation, oil rights, citizenship, slavery, etc., that most such boundaries have been fixed by agreement to be the river channel as of a certain date. This is not entirely satisfactory, because the river keeps changing, and laws, roads, and civil allegiance are hard to maintain when small chunks of states or nations are isolated on the wrong side of major rivers.

Once a meander is cut off and left behind as an oxbow lake, its life is one of seclusion with gradual filling by clay, turtles and bullheads. Floods periodically bring more clay and remove the bullheads, making a deposit called a clay plug.

Clay plugs make up hard banks difficult for meanders to erode; an impinging meander distorts and wraps around but can't get by, so it is cut off, renewing the cycle. Clay plugs therefore beget more clay plugs, an asexual reproduction. On wide floodplains clay plugs also fence the area of active meandering, making it a meander belt.

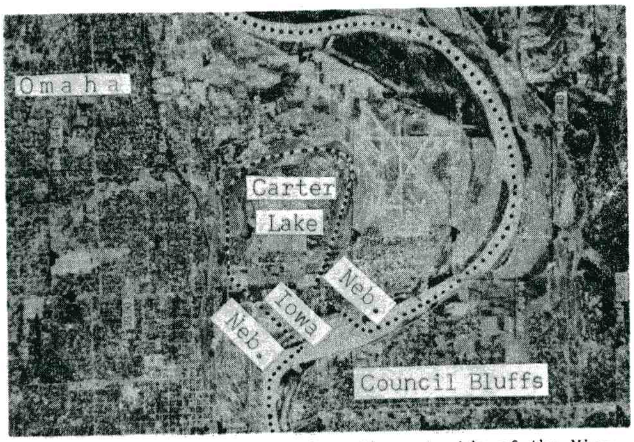
Neck cutoff at the right gave an oxbow lake, also pictured on p. 1. Meander loop was innocently migrating downstream when it bumped into an old and obstinate clay-filled oxbow (cross-hatched). Delay in migration allowed the next meander to catch up and cut off. Blue Lake, near Onawa, Iowa.



OVERBANK DEPOSITS

During flood all manner of items may come tumbling out over the river banks, including water snakes, muskrats, chickens, bathtubs, privies, and wet neighbors. In fact, on the river one hardly expects to enjoy the same outdoor plumbing two floods in a row unless he has the affectionate foresight to provide it with an anchor. Houses can be put on stilts, but there's no easy answer for privies.

Other materials over the banks include sand, silt, and clay, plentifully diluted with water. With the lowered water velocity, transported sediment begins to settle, coarser materials near the river and finer materials farther out. One result is natural levees, which occur as long, low ridges along the river, as the name implies. Turn the page.



Neck cutoff left a dry spot on the wet side of the Missouri river. (Iowa is dry.) Both Carter Lake and the Omaha airport are on point bar sands. In recent years, U. S. Army Corps of Engineers control measures have "tamed" much of the river channel, confining it so it will stay put and scour deep enough to be navigable.

Natural levees are characteristically fine sand and silt grading outward into clay. They are tens of yards to miles wide, with a height at the crest which may almost match the maximum flood stage. The "almost" is significant, particularly where the river bed is filling and raising the river level, for example because of delta building and extension of the mouth, until the natural levees confine the normal river above floodplain level. This is convenient for irrigation but you need a herd of small boys with fat fingers ready in case of emergency. The Hwang Ho (Yellow) River of China is a classic example; water topping the natural levees quickly cuts a crevasse and pours out on the floodplain, inundating thousands of square miles of fertile land as well as innumerable likewise Chinese.

Small natural levee on the enchanting Skunk River (ah, odor) at our town of Ames. The levee slopes down and fades out to the right. Trees were probably pushed askew by the periodic flooding.

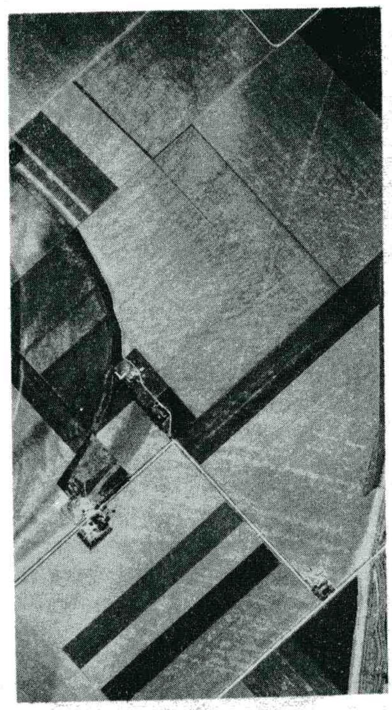
Sometimes the combination of natural levees and clay plugs effectively fences off tributaries from the main river. The victims meander miles before they are let in, often as not where the main stream carelessly crowds them against a valley wall. Such bullied tributaries are called yazoos, after the Yazoo River, in the state of Mississippi. As it turns out the Yazoo River is not a very typical yazoo, but the name is such pure poetry it probably will be retained.

Crevasses

A surficial floodplain deposit with a garrish appearance on aerial photographs comes from crevassing of levees during floods to give braided flood distributary channels. The braided appearance and light color foretell thin sands and silts, but they are usually over clay.

Backswamps

Farther out on the floodplain, beyond the natural levees, fine silt and clay settle, gradually accumulating many feet of thickness and obscuring older point bars, clay plugs, fences and sleepy hogs. These deposits are the backswamp clays or slack water deposits. Thin clay layers of similar origin also cover all but the latest point bar sands, particularly in the low places or swales.



Natural levee with crevassing, located along a now abandoned braided channel a mile northeast of Blair, Nebraska. Natural levees never die; they just fade away into backswamp clay (right).

MISSOURI RIVER DEPOSITS

For bountiful big-river shorelines we present to you the state of Iowa, hot and dry, and bounded by the Missouri River on the west and the Mississippi on the east.

Actually the Missouri is a rather recent immigrant, and even the Mississippi has jumped around a bit. The Missouri once flowed northward into Hudson Bay until the glaciers crowded it out, along with the mammoths, musk oxen, and a few other things. Now the Missouri serves as a rough marker of the maximum southward extent of continental glaciation.

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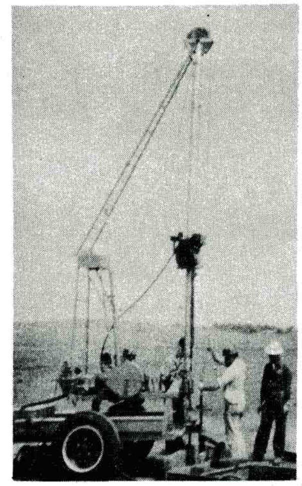
MISSOURI RIVER DEPOSITS (Contd.)

Of our two big border rivers the Missouri, "Big Muddy," left the lustiest smear, the floodplain being up to 18 miles wide. The floodplain is fertile and is therefore mostly in Iowa; Nebraska got steep banks and sand bars. In other words, the river keeps working against the right hand side. The reason may be partly because of earth's rotation; streams, winds, and bullets are slightly deflected to the right in the northern hemisphere,* which can be rather tough on conservatives.

In her caper along Iowa, the Missouri cuts a triple-threat figure, being widest at the top and narrowest down around the knees. From Sioux City to Crescent, the wide floodplain consists of an active channel belt 1 to 3 miles wide; a recognizable meander belt, including the channel belt, 5 to 13 miles wide, and a relatively featureless area of flood basin deposits, backswamp and fans, for the remaining 1 to 12 miles. Adjacent hills whose toes were cut off by the river (photo top p. 2) are composed of glacial drift capped with thick loess.

South of Crescent, the Missouri wears a girdle; bedrock confines the floodplain to 4 to 5 miles wide. As might be expected from such a pinch at the vitals, the floodplain is mostly active channel and meander belt, with very little of the featureless flood basin deposits.

The next major change in environment is the entry of a wild neighbor from the west, the Platte River. The Platte is a heavily loaded, braided stream, and suddenly the sediment load in the Missouri is doubled without very much increase in the amount of water. Therefore downstream from this point the meanders are much straighter, giving a steeper gradient, and the channel is wider and shallower and begins to look a bit braided. Floodplain point bar and clay plug deposits are thinner because of the shallower stream, and some of the bars have been blown around a bit by wind.

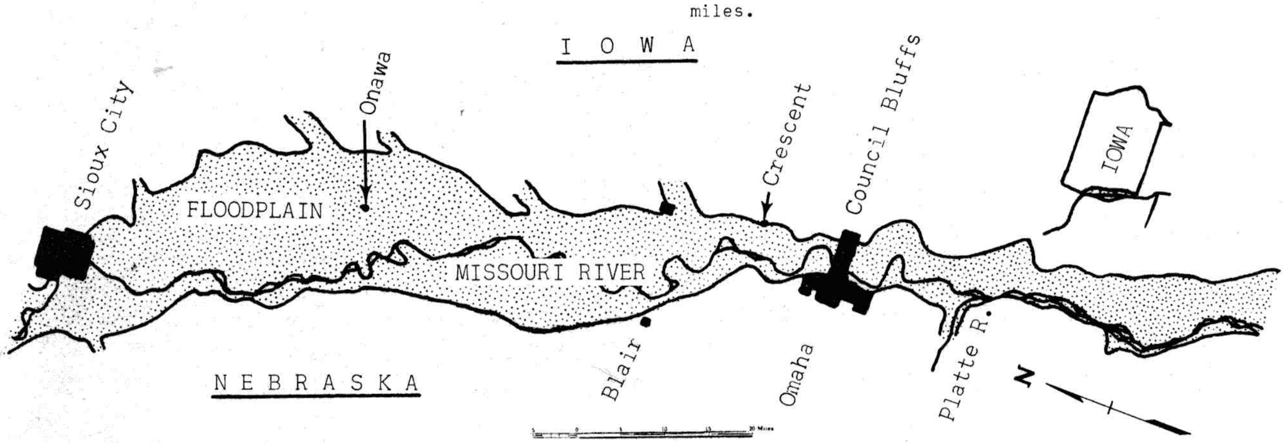


Engineering

Engineering soil maps of floodplains may be readily made from air photos because meander features and braids show so clearly. Maps for the Missouri River floodplain have recently been prepared, and engineering properties of soils spot checked from field samples.

Point bars. Point bar samples classify as sand or sandy loam, A-3 soils. That means good. On top of the sand is a variable thickness of clay + silt which generally classifies as A-7 and is analogous to backswamp deposits. Not so good. Thickness of the top material ranges from 0 to less than 20 feet, the thicker deposits causing veiling of the original hummocky point bar topography as seen on air photos.

* This is the Coriolis effect (mathematics): Velocity is a vector quantity which includes both speed and direction. Therefore when you whiz around a corner on a motorcycle you change velocity, for example from east to south. Accept this and the rest is easy; a change in velocity must mean an acceleration, and from Newton's law this means a force directed radially to oppose the so-called "centrifugal force." The earth's rotation changes all velocity vectors on the earth's surface, meaning acceleration and a force directed radially perpendicular to the earth's axis. In the northern hemisphere the horizontal component of this force comes from the right or rivers, winds, and bullets will drift to the right. Didn't think we could do it, did you? Uninfluenced by other factors such as downhill, a river flowing 2 mph at a latitude of 60° would travel a circle with radius 8 miles.



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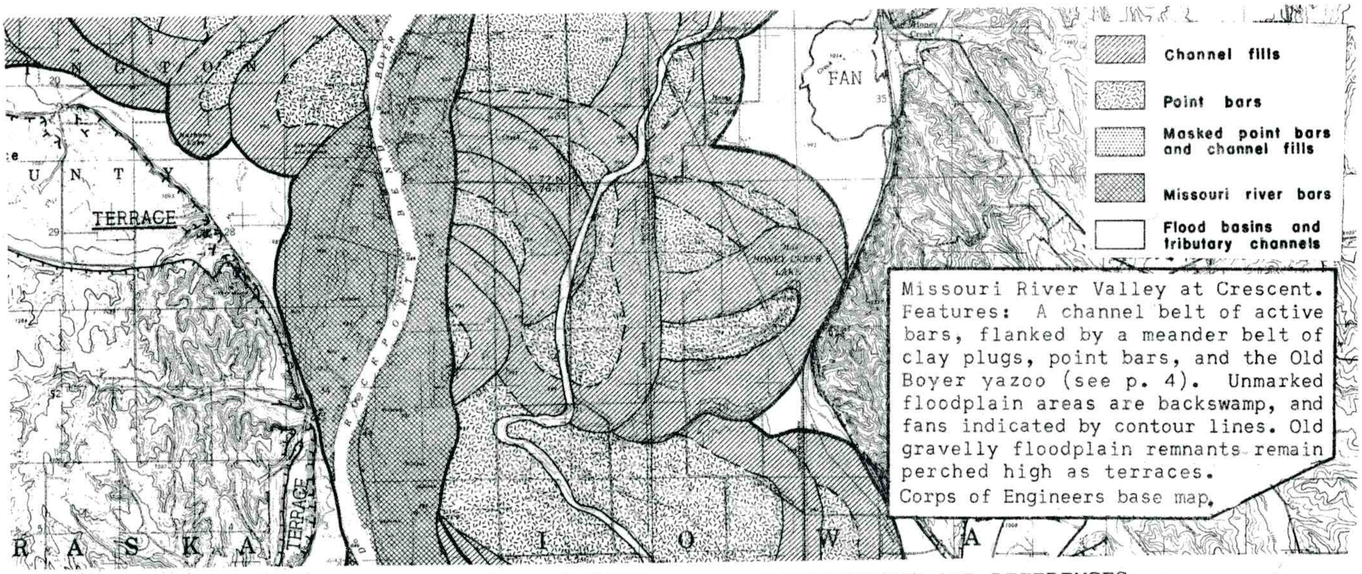

Missouri River Valley at Crescent. Features: A channel belt of active bars, flanked by a meander belt of clay plugs, point bars, and the Old Boyer yazoo (see p. 4). Unmarked floodplain areas are backswamp, and fans indicated by contour lines. Old gravelly floodplain remnants remain perched high as terraces.
Corps of Engineers base map.

Clay plugs. Abandoned oxbow channel fills are usually clay classifying as A-7, 20 or more feet thick, and to be avoided.

Natural levees and backswamp. Natural levees are most prominent in the upper and middle segments of the floodplain. Samples usually classify as clay, but may be A-4, A-6, or A-7. Material is coarsest at the crest, and becomes finer away from the channel, grading into backswamp clay, A-7. The backswamp is not good for engineering structures, but is usually unavoidable.

Fans. Fans from the tributary valleys are locally important, and usually classify as silty clay loam, A-6 or A-7. They occur along the floodplain margins plastered on top of the primary floodplain deposits.

Substratum

Borings reveal that underneath all of the surficial materials described above is sand and gravel hiding a canyon 70 to 150 feet deep. This sandy substratum is easily reached by pile for the support of large engineering structures, and under point bars grades imperceptibly upward into the point bar sands which are relatively shallow.

Origin of the substratum sands and gravels is a tricky question currently being investigated with deep boring equipment. A likely possibility is valley filling during the last glacial melting; sea level came up some 300 to 400 feet, and raised the river base levels. Sand and gravel for valley fill were plentiful from the melting glaciers. On the other hand glacial geologists have found that terraces merge into the upland at or near ice sheet margins, suggesting a similar deposition of coarse material occurred during ice maximum, when sea level was lowest. Problems, problems...

ACKNOWLEDGEMENTS AND REFERENCES

Systematic relationships and nomenclature of meandering stream deposits largely stem from work in the lower Mississippi Valley by the fathers of the waters, H. N. Fisk and R. J. Russell; see Fisk, "Fine-grained alluvial deposits," U. S. Waterways Experiment Station, 1947. A recent summary of meandering mechanics is "River meanders," by L. B. Leopold and M. G. Wolman, Bull. Geol. Soc. Am., 71:6: 769-794. 1960

Studies of the Missouri River floodplain are being conducted under sponsorship of the Iowa Highway Research Board, Project HR-1, with funds from the Iowa State Highway Commission. Also participating is the Iowa State University Geology Department utilizing grants from the Geological Society of America and from the Office of Naval Research, Project NONR-2991(00). Special acknowledgement is made to the U. S. Corps of Engineers, Omaha District Office, for continuing help and sympathy during the investigation. Preliminary data and maps are contained in an M. S. thesis by J. L. Glenn, "Missouri River Studies: Alluvial morphology and engineering soil classification," Iowa State Univ. Library, 125 pp., 1950. This soon will be out as a Progress Report.

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