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GROUNDWATER AQUIFER PATTERNS AND VALLEY ALLUVIATION ALONG MOUNTAIN FORK CREEK, CRAWFORD COUNTY, ARKANSAS

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INTRODUCTION

An alluvial valley fill study was undertaken in the summer of 1965 in the Boston Mountains of northern Arkansas. It was an attempt to discern the pattern (if any) of alluviation and aquifer development, using electrical resistivity and auger boring techniques. Alluvial deposits in the valley of Mountain Fork Creek, Crawford County, Arkansas, selected for study are representative of similar accumulations throughout the region on several counts. (1) Rocks of Mississippian and early Pennsylvanian age comprise the valley floor and walls; (2) local bedrock includes shale, sandstone, siltstone, and limestone with siliceous, ferruginous, and calcareous facies of essentially all of these plus minor chert; (3) strata are generally flat-lying or gently inclined to the south (½° to 1°) and are only locally and slightly disturbed by minor faults and gentle folds; (4) general inclination of strata is only slightly less than the similar southerly gradient of Mountain Fork Creek so that reaches of the valley floor and lower walls 1 to 3 miles long comprise essentially one formation and lithology and are replaced to the south by similar reaches of successively younger, lithically distinct units.

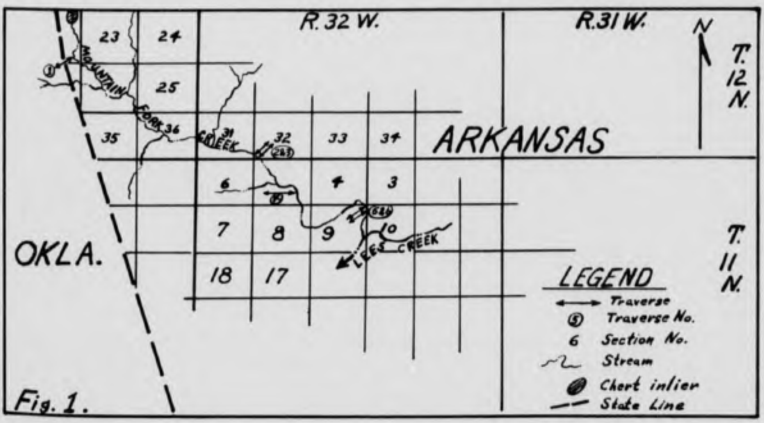

Fig. 1.

The valley of Mountain Fork Creek was also selected for study because of one unique feature. In the headward reaches of the stream (Map, Fig. 1) there is an inlier of chert and cherty limestone strata referable to the Boone Formation of Mississippian age. This inlier is the only bedrock source of fragmental white chert within the Mountain

Fork Creek drainage basin. The main channel of the creek has incised the cherty strata some 40-50 feet and one can conclude that chert clasts have been available to down-valley areas for an extended period of time. In addition, because said chert has not been utilized locally for construction purposes, chert clasts associated with Mountain Fork Creek valley alluvium may be inferred to have come from said inlier. The Boone chert is unlike any other bedrock exposed in the valley and the chert clasts are readily distinguished in alluvial deposits even where present in only trace amounts.

The presence of the above-discussed chert inlier led the writer to direct a graduate student at the University of Arkansas (Medina, 1962) in a sedimentological thesis study of the Mountain Fork Creek alluvial deposits. The principal purpose of that thesis study was to determine how the alluvium had been deposited. If emplaced by a laterally corrading and depositing stream, essentially the entire alluvial fill should contain scattered chert clasts. But if the alluvium had been latterally introduced by valley wall erosion and scarp retreat only those parts of the alluvium later reworked by the stream would contain chert.

In brief summary, Medina (1962) concluded that chert was limited to gravels along the present stream channel and further that these stream channel gravels exhibited sedimentological parameters distinct from the remainder of the valley alluvium, being better rounded and better sorted, showing rapid size reduction in a down-valley direction, and rarely containing appreciable sub-sand-size material or metastable rock fragments. According to the same study the remaining valley alluvium contains metastable limestone clasts, is everywhere poorly sorted with large amounts of sub-sand-size material, and only shows appreciable clast size reduction away from the valley sides toward the main drainage line with some rounding in the same direction, both at a much slower rate per unit distance than for similar clasts in the stream channel gravels. Medina (1962) concluded that the great bulk of the Mountain Fork Creek valley alluvium was introduced laterally by a high-density transport medium which moved only short distances (presumably sheet floods and mud flows operating in a rigorous, non-vegetated and probably arid environment).

This writer concluded from Medina's study (1962) that drastically different groundwater aquifer characteristics and depositional patterns should be associated with each of the two principal components of the valley alluvium to the extent that they exist. The present report represents an attempt to test this idea. To this end, an earth resistivity apparatus constructed to federal specifications by the Arkansas Highway Department was obtained on a loan by the Arkansas Geological Commission. The latter commission later drilled some 12 auger holes to test alluvial thickness indicated by resistivity data.

The writer is indebted to the Arkansas Geological Commission and particularly to Mr. Norman F. Williams its director for financing field work and supplying instruments and boring equipment. The Office of

Water Resources Research of the University of Arkansas made the completion of this report financially possible.

INSTRUMENT TECHNIQUES

A total of six cross-valley resistivity traverses were completed along Mountain Fork Creek with an average of one sounding station per 100 feet of traverse length. Spacing was somewhat closer where the location of stations was keyed to subtile changes in alluvial topography believed to be tied to lithologic variations. In all, there were 68 separate resistivity sounding stations. The number of sounding readings per station averaged four, was at a minimum two, at a maximum nine and in each case was extended to include some bedrock.

The resistivity sounding technique used relied upon a four-electrode system (two steel stakes and two porcelain pots filled with copper sulphate) with an initial ("a") spacing of three feet. Depth calculations were made by the Barnes Layer Method and these satisfactorily showed individual layer resistivities. In all, data from ten instrument stations was checked by drilling to bedrock and in all ten sites data from the four-electrode setup pinpointed the alluvial-bedrock contact within a specific 3-foot interval.

Apparently depending somewhat on water content (which in surface layers varied with short-term precipitation) there appear several lithologic-resistivity relations of considerable constancy. (1) A near-surface layer frequently encountered is a dark-brown, silty — probably loessal — loam with resistivities of 0.52 million ohm centimeters where high in clay and moist, to 4.1 million ohm centimeters where very dry, sandy, pebbly and/or clay lean. (2) Coarse alluvial gravel layers show resistivities from 4.0 to 6.5 million ohm centimeters without consistent regard to apparent water content — the lower readings occurring where much silt and/or clay is present in the matrix and some of the higher values occurring in water-saturated layers that were clay lean. The adhered moisture on the clay minerals may be more conductive.

With regard to bedrock, silty shale beds of the upper Fayetteville Formation and younger Morrowan silty shale beds had resistivity values of 8 to 11 million ohm centimeters. Siliceous siltstones, calcareous sandstones and limestones show resistivities from 13 to 150-plus million ohm centimeters. Clay shale of the lower Fayetteville Formation consistently reads 1.8 — 2.1 million ohm centimeters.

From the foregoing discussion it is readily apparent that the only bedrock resistivity values in the area that might consistently compare with values in overlying alluvium are those found in the lower Fayetteville Formation. On the basis of magnitude alone, bedrock-alluvial contacts could not be picked in a traverse across that formation. However, it was there observed that alluvial-resistivity values fluctuated, presumably because of variations in compactness, gravel, clay, and moisture content, whereas shale-resistivity values were consistently of a single value over considerable depth intervals.

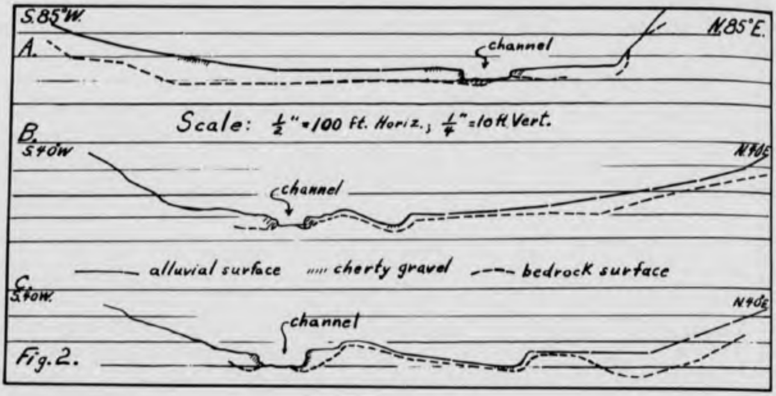

Fig. 2.

RESISTIVITY SOUNDING TRAVERSES

A total of six resistivity sounding traverses were completed along the valley of Mountain Fork Creek and their locations are shown (Fig. 1). Traverse 1, a mile downstream from the chert inlier, crossed a pediment slope and valley flat developed on shale of the Mississippian Fayetteville Formation. The cross-profile illustrated (Fig. 2,a) shows a bedrock alluvium contact with distinct valley flat and side wall cloaked with an average thickness of some 5 feet of detritus which observation indicated was essentially chert free and largely shale debris from subjacent bedrock. Remnants of a cherty alluvial terrace were noted some 10 feet above the present channel along the valley margins. Alluvium in the present stream channel carries a chert admixture as does a gravelly depression (flood overflow line) extending down valley from a bend in the stream channel upstream from the resistivity traverse.

Traverses 2 and 3 are a pair spaced some 300 feet apart, trending across a generally straight and symmetrical portion of the valley some five miles downstream from the chert inlier. As illustrated (Figs. 1; 2, b-c) an average of only some 2-3 feet of alluvium coats the pediment crossed by the traverses and the bulk of the clasts in the coarse, angular gravels observed were similar to siliceous siltstone and ferruginous sandstone exposed in the subjacent Pennsylvanian strata. All of the alluvium in the valley appeared to be chert free except that in immediate association with the present stream channel and a thin veneer in a dry slough (flood overflow route) fringed on the valley-wall side by an abrupt rockcut terrace some 5 feet high. Probably the outstanding disclosure of a study of the resistivity data along traverses 2 and 3 was the fact that two portions of the bedrock valley floor were on a level with or lower than bedrock in the present stream channel. Further, it is important that a topographic high with a bedrock core separates the abandoned slough and the present channel. The absence of chert from most of the alluvial fill and the presence of bedrock obstructions between flow routes clearly demonstrates that the stream did not attain its present position by means of any system of lateral corrasion or cut-fill migration. No remnant of a chert-bearing, high level alluvial terrace was observed.

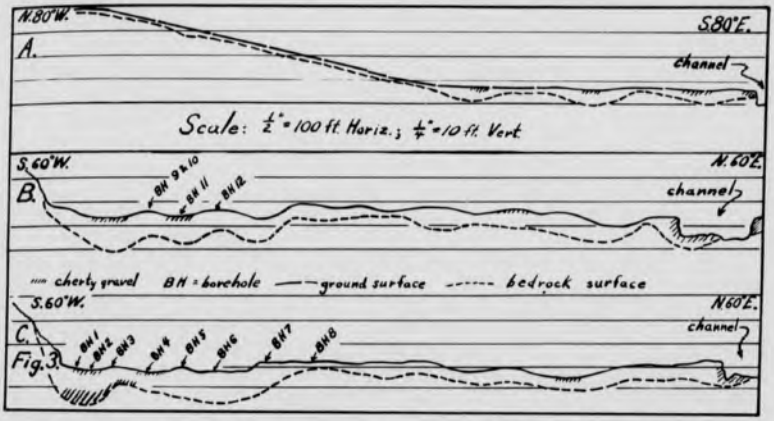

Fig. 3

Traverse 4 extends across a pediment slope and valley flat just below a sharp bend in the creek channel 6 miles down-valley from the chert inlier. As illustrated (Figs. 1; 3,a) the resistivity data showed a 2-3-foot-thick alluvial veneer across the pediment and adjacent valley flat. Excepting flood overflow swales with minor cherty gravel fills and along the main channel the alluvium in the valley is chert free, generally argillaceous and impervious. Several swales developed in bedrock below thin alluvial covers have elevations lower than bedrock in the adjacent open creek channel and this relation plus the chert free character of much of the valley gravel precludes alluviation by lateral channel sinuosity oscillation through cut and fill.

Traverses 5 and 6 represent a second pair spaced some 300 feet apart and generally bisecting a valley flat on the concave side of a large "meander" bend in the channel of Mountain Fork Creek (Figs. 1; 3,b-c). Twelve of the resistivity stations were auger-drilled to bedrock. A greater alluvial thickness (average 6-8 feet) was encountered in this river bend on the valley than on traverses 1-4 and several aquifer relationships were indicated. Water saturated cherty gravels occupy two bedrock swales that are expressed on the alluvial surface by flood overflow routes. The bedrock bottoms of these swales are 6-8 feet below the bedrock under the present stream channel and are separated from that channel by bedrock rises. The alluvium across the valley flat is generally chert free though alluvial gravels in flood overflow swales contain local patches of chert and chert is mixed with other lithologies in gravels in the main channel.

The chert-free character of much of the alluvium in the vicinity of traverses 5 and 6 shows that the stream did not attain its present channel position by cut and fill shifts from a slip-off slope. Cherty gravel patches along the bottoms of bedrock swales show earlier occupation of these swales by channeled runoff and account for the aquifer character of the gravels in these swales. Saturation of these gravels in this instance is believed to reflect the local natural impoundment of water in the present channel of the creek above the formation known as Natural Dam. A hillside seepage appeared to have saturated a patch of gravel in a small alluvial fan near traverse 3 but other gravels observed in the valley of Mountain Fork Creek appeared unsaturated during the dry months of the survey (July, August, 1965). Furthermore, only the cherty gravels that have been handled by throughflowing channeled runoff appear to be sufficiently well sorted to act as aquifers. These generally seem to give up contained water to the stream as water levels fall in the latter.

ALLUVIAL PATTERNS

A study of the alluvium along Mountain Fork Creek by resistivity, auger boring and observation has disclosed several existing relations. In general the detritus which sheaths the pediment slopes is thin (3-5 feet thick), chert free and appears generally impervious and poorly suited for aquifer purposes. It tends to closely reflect subjacent bedrock in lithic content but is in any case a more or less intimately mixed association of sand, silt, clay and gravel including some boulders. In many places this non-sorted, closely packed mixture forms a type of "hardpan" that sheds water like cement and appears dry only a few minutes after a heavy rain. The larger clasts are an assortment of sandstone, siltstone, shale plus occasional limestone fragments, all more or less angular in shape.

The valley flats along Mountain Fork Creek combine the alluvial debris described above with two other types of material. The bulk of the valley flats seem to be buried with essentially the same type of angular, poorly sorted, chert-free detritus. Where the present stream channel has incised and reworked this valley fill it contains an admixture of white, angular chert clasts, includes many well-rounded pebbles and cobbles and very little silt or clay. It seems pervious and of probable aquifer caliber although most of this debris is close to the main channel and drains immediately back into the stream as water levels fall after rains.

Cherty material has additionally been incorporated into the valley fill where flood overflow sweeps across it down-valley from sharp channel bends. Such overflow lines (Fig. 4) usually follow the most direct down-valley routes and have steeper slopes than the main stream channel. Many are expressed as shallow swales in the surface micro-topography of the valley-flat alluvium. Not all swales show surface gravel material but auger borings into several disclosed rather thick cherty gravel fills. Three swales which seemed to extend downslope to an area of natural impoundment contained water saturated cherty gravel apparently of aquifer quality.

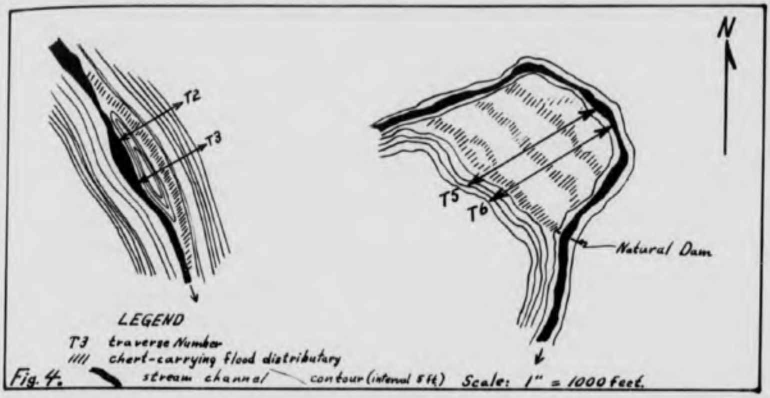

Fig. 4.

These cherty, valley-floor deposits are actually in flood distributaries, consequent on a pre-existing, non-cherty alluvial fill. The swales diverge, converge and generally anastomose across the older alluvium and locally exhibit patches of coarse, cherty surface gravel (high-water point-bar deposits). The patterns are reminiscent of drainage patterns developed elsewhere on a larger scale and described by the writer (1966). Some of the cherty gravel in the swales actually rests on bedrock and may date back to a time of early valley incision and/or to some prior incision of the alluvium to bedrock. In any event, the gravely composition of the alluvium under the swales as shown by auger boring makes it clear that the swales are not of compactional origin. They appear to be swales because erosion and deposition both occur within them and the most recent events in many were erosional.

The third sedimentary increment recorded across many valley flats along Mountain Fork Creek is a tan-brown silty interval underlying the surface of many alluvial swells. At least some of this material is probably loess, for it is mainly silt and wind-deposited materials are widespread across the region. Some may have been waterlaid in areas of temporary impoundment such as that just above Natural Dam (Fig. 4).

RECENT FLUVIAL HISTORY

The recent history of fluvial events in the valley of Mountain Fork Creek would include several distinct stages of development. (1) Erosion of a relatively narrow, v-shaped valley 200-300 feet deep and exposure of the Boone chert inlier — the through-flowing stream that accomplished this presumably reflects humid conditions and left thin patches of chert pebble gravel along its channel ½-1 foot thick, presumably when runoff decreased and it ceased to erode. (2) Localized fluvial activity subsequently coincided with the development of valley flats and pediments which appear to have been simultaneously alluviated, the former to depths of 10-15 feet. The agents that deposited the poorly sorted debris were probably arid sheet floods and mudflows which dried up and held, the principal bedrock types (chert, sandstone and shale) close to their respective outcrop areas and short reaches (1-2 miles) downvalley from these. More than two miles below the Boone inlier, the bulk of this alluvium is chert free. (3) Through-flowing running water then swept the alluviated surface (probably with increasing rainfall) removing 5-10 feet of material near the valley mid-line, re-exposing the Boone inlier and ultimately scouring multiple channels, some to bedrock. (4) Through-flowing channel-confined runoff subsequently lost transporting power, (probably as rainfall diminished) alluviated the multiple channel system with relatively cherty, well-sorted gravel to a level somewhat lower than that of the principal alluvial fill, and created a swell-swale alluvial topography. (5) Subsequent incision continuing to the present reflects humid conditions and the through-flowing runoff has deepened a new channel, locally to bedrock (probably along an old swale route) which is currently incapable of containing high-volume runoff — overflows across adjacent alluvial flats are most pronounced downvalley from sharp bends which appear to back-up flow and valley flats appear to be currently undergoing more erosion than deposition. Admittedly, some floods have left gravel banks in overflow swales but such deposition must be regarded as temporary.

Swells on Mountain Fork Creek valley flats presently exhibit rather thick caps of silty loam in most places and only rarely a few scattered clasts of sandstone and siltstone. Related studies of the general area indicate that much of this silty material is loess, blown in from arid areas to the west. And though some dust is undoubtedly accumulating at present, the valley alluvium probably had such a surficial layer prior to present incisional processes. Locally the surficial silt has been washed into depressions and includes pebbles.

One aspect of present findings is particularly interesting and important. The floods (here defined as over-bank flow) that periodically innundate the valley floor of Mountain Fork Creek are of a climatic origin. No single channel capable of containing present runoff maxima exists and none has been recently permitted to form and deepen without aggradational interruption. The consequent runoff forms primary drainage networks during floods and the stream closely resembles those discussed by the writer (1958, 1959, 1966) from other regions repeatedly subject to arid-humid climate changes. A geomorphic history for the Ozark Dome involving such climate changes has been proposed by Quinn (e.g., 1965).

ALLUVIAL GROUNDWATER EVALUATION

The present study delineates several alluvium-aquifer relations for Boston Mountain drainage systems. Specifically with regard to Mountain Fork Creek, the bulk of the valley is too thinly alluviated to provide extensive alluvial groundwater along long reaches. Also, many of the thicker alluvial sections are composed of poorly sorted colluvium in the form of small valley-side alluvial fans. Only where these accumulations have been subject to valley-side runoff from springs and tributaries have fine clastic fractions been flushed away and in some cases such gravels are a potential source of groundwater. Elsewhere in the valley, only the alluvium that has been subjected to through-flowing runoff exhibits a degree of sorting approaching aquifer caliber. The bulk of such material is found in direct association with the present main stream channel and in thick channel-fill sections on the valley flat where alluvial depths carry below the water level in the main stream. Bore holes encountered water under such relationships. It should be emphasized that channel fills of aquifer caliber are close to and essentially parrallel to the main stream channel except directly downvalley from sharp bends in the channel or on the concave side of large bends where overflow has affected large portions of the valley flat. Also, in the latter areas alluvial thickness seems greatest, and water-well locations in such sites appear to have the greatest potential.

Alluvial aquifer development along the valley of Mountain Fork Creek may or may not typify that in other valleys of the Boston Mountain region. The matter requires additional study in streams of different magnitudes and in areas where there are other bedrock types and channel patterns.

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