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Depositional environments as a guide to uranium mineralization in the Chinle Formation, San Rafael Swell, Utah

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Depositional environments as a guide to uranium mineralization in the Chinle Formation, San Rafael Swell, Utah[1]

By Robert Lupe

Abstract

Uranium deposits in the San Rafael Swell are related to sedimentary depositional environments in the Triassic Chinle Formation. The sedimentary textures resulting from depositional processes operating in lower energy environments appear to have influenced uranium mineralization. The Chinle consists of three fining-upward, fluvial-lacustrine sequences. Uranium mineralization is concentrated in the lower part of the lowest sequence in areas where sediments of lower energy environments are complexly interbedded with sediments of other environments. Areas favorable for uranium exploration exist in the subsurface to the north, west, and south of the Chinle outcrop in the Swell. This determination is based on the spatial distribution of depositional environments and the pattern of Chinle deposition through time.

Introduction

Uranium deposits in the San Rafael Swell, Utah, are spatially related to rocks of certain depositional environments in the Triassic Chinle Formation. This relationship can serve as an important guide in selecting areas favorable for uranium exploration.

Many workers in the Colorado Plateau during the uranium "boom" of the '50's concluded that the texture and composition of the host rock helped control uranium mineralization (Finch, 1959, p. 144; Fischer, 1974). The rock compositions and textures resulted from the sedimentary processes unique to each depositional environment; hence, the distribution of the rocks of certain depositional environments may be similar to the distribution of uranium host rocks.

The distribution of uranium deposits is also similar to the distribution of collapse features and the distribution of potential source rocks. These factors will be discussed briefly.

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[1]Based on talk given at the U.S. Geological Survey Uranium and Thorium Research and Resource Conference held December 8-10, 1975 at Golden, Colorado.

This report is the first part of a study of the sedimentary geology of uranium-bearing Triassic rocks of the Colorado Plateau. Michael Reyes assisted in the field.

Geologic setting

The San Rafael Swell is a doubly plunging, asymmetric anticline formed in early Tertiary time (Gilluly, 1929, p. 126). The Chinle Formation is exposed around the flanks (fig. 1). The Swell lies south of the Uinta Basin and, except for a few outcrops north of the Uinta Basin, the outcrops in the Swell are the northernmost exposures of Chinle on the Colorado Plateau.

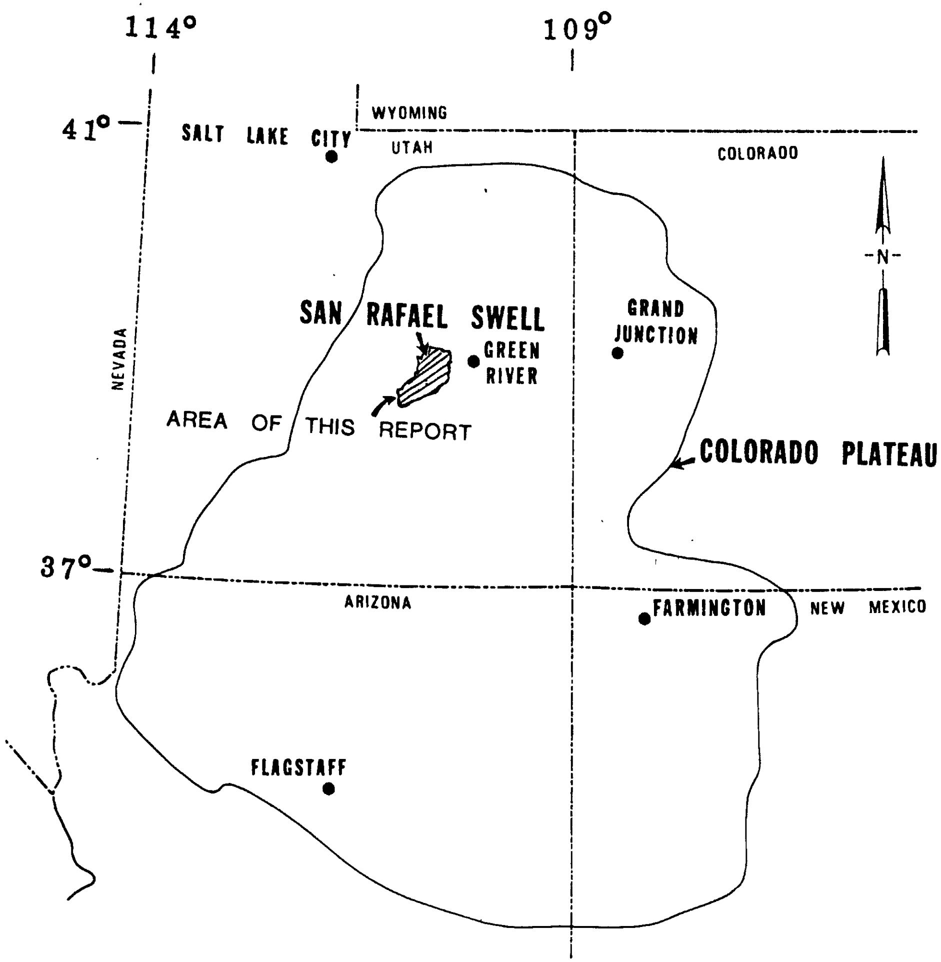
Objective

The objective of this study was to determine the areal and stratigraphic distribution of depositional environments in the Chinle and their relation to uranium host rocks. Depositional environments were interpreted and rock textures and compositions were noted at each station shown on figure 1. Transport directions were also determined and were used to project outcrop observations into areas where the Chinle was not exposed.

Results

The stratigraphic distribution of rocks of various depositional environments is shown on cross sections A-A' and B-B' (fig. 2). The Chinle consists of three fining-upward sequences with each sequence generally finer grained than its predecessor. The sedimentary rocks also grade laterally from a main area of deposition into finer grained rocks.

Each sequence generally grades upward and laterally from proximal braided stream sandstones and conglomerates, through distal braided stream sandstones, floodplain or overbank fine-grained sandstones, siltstones, and mudstones, to lacustrine siltstones and mudstones. The sequences are commonly capped by paleosols. This sequence of depositional environments reflects a gradual change to environments of lower energy as deposition continued. The sequences also indicate



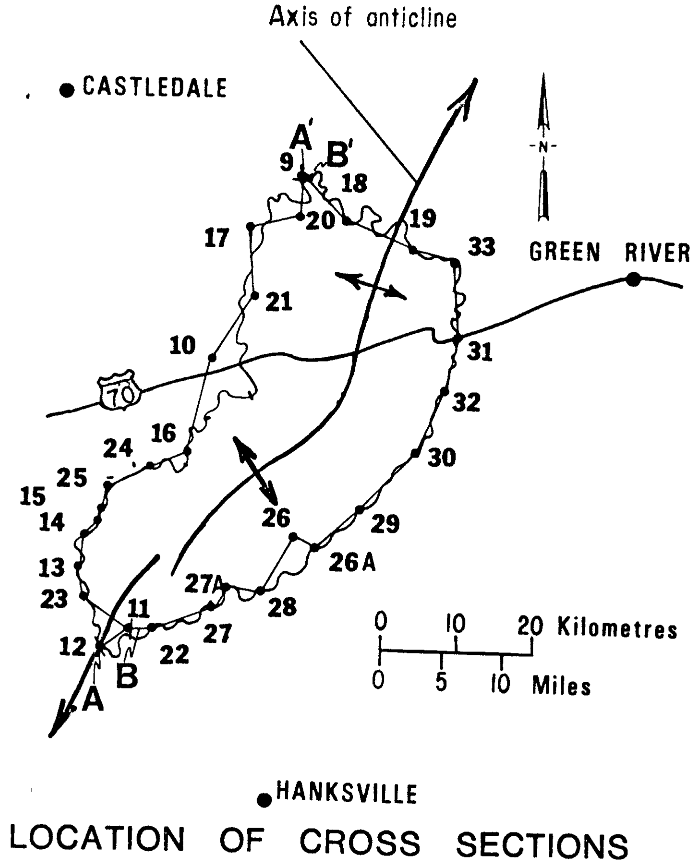


Figure 1.--(A.)Location of the area of the report; (B.) the location of cross sections A-A' and B-B', and the location of sample stations.

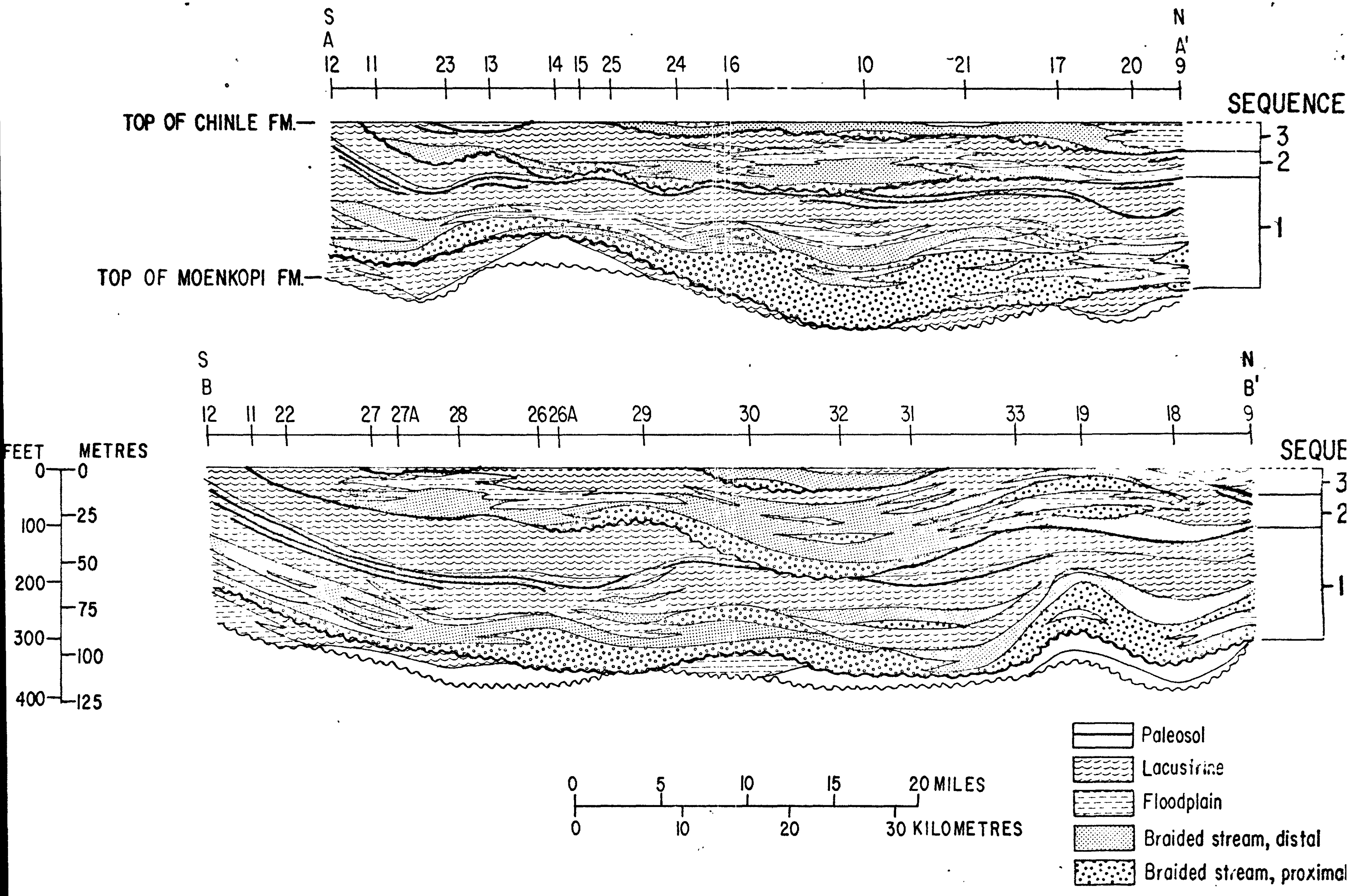


Figure 2.--Cross sections showing sedimentary depositional environments of the Chinle Formation, San Rafael Swell, Utah. The lower part of Sequence 1 is roughly equivalent to the Moss Back Member of other workers (Stewart, Poole, and Wilson, 1972, p. 31).

an increase in the distance from source area or a decrease in relief during later stages of deposition.

The lateral and vertical distributions of depositional environments are similar. The lateral decrease in grain size indicates a trend toward lower energy depositional environments away from the main locus of deposition in the middle part of the Swell (fig. 2).

The diagnostic criteria used to distinguish various depositional environments are as follows. Proximal braided stream deposits (fig. 3a) are conglomeratic sandstone containing ripped-up intraclasts near their strongly erosional bases. They reflect the highest transport energies during Chinle deposition. Their sedimentary structures are relatively simple, consisting mainly of unstructured and flat beds. There is little vertical change in grain size. Proximal braided stream rock bodies are lenticular in cross section, and foreset bedding and channel axes indicate unidirectional transportation.

The distal braided stream deposits, which usually overlie and laterally abut more proximal braided stream deposits (fig. 2), contain sand-sized sediment that is finer grained than more proximal deposits and that is commonly typified by the tabular foreset bedding of transverse bar origin (fig. 3b) (Smith, 1970, p. 3000; Asquith and Cramer, 1975, p. 660). Sediment transport was also unidirectional.

Floodplain or overbank deposits can be confused with lacustrine sediments where outcrops are poor. Floodplain sediments show abundant subareal features, such as mud cracks, tracks, and sediment tubes disgorged by feeding animals. They are commonly rhythmically bedded and show unidirectional flow features, and are less burrowed and are coarser grained than lacustrine beds (fig. 3c). On the other hand, lacustrine beds lack bedding due to heavy burrowing, they show little evidence of subareal exposure, and they are generally finer grained (fig. 3d).

A

B

C

D

E

Figure 3.--Sediments of various Chinle depositional environments: (A) Proximal braided stream deposits exposed in cliff; (B) distal braided stream deposits showing typical foreset bedding; (C) rhythmically bedded overbank deposits; (D) heavily burrowed lacustrine beds; (E) a typical, rubbly weathering paleosol.

Paleosols (fig. 3e), common at the top of these fining-upward sequences, are both calcareous and siliceous. They formed in a semi-arid climate (Cooke and Warren, 1973, p. 114).

One feature deserving special attention is the complex interbedding of rocks deposited in various depositional environments near the north and south ends of the Swell (fig. 2). In these areas the sediment bodies are also generally smaller. This complex interbedding may have played an important part in control of uranium mineralization.

An aid in reconstructing the areal distribution of depositional environments is to examine transport directions for various, specific horizons in the Chinle. Transport directions for the lower part of Sequence 1 are shown in figure 4. The rose diagram defines a strong northwesterly transport trend with minor divergence. Geographically, that strong northwest trend is represented by a corridor of deposition across the central part of the Swell (fig. 4). The divergences from the strong northwest trend in this interval of the Chinle are in the north and south ends of the Swell where streams trended slightly away from the axis of the corridor. This pattern suggests that currents were weaker in the north and south. This inference is supported by the greater abundance of lower energy environments in these areas (fig. 2).

A paleogeographic reconstruction of the lower part of Sequence 1 is shown in figure 5. Environments are generalized from figure 2. These environments were tied together schematically using transport trends (fig. 5).

These studies indicate that a system of predominately braided stream sediments trended toward the northwest across the central part of the Swell during early Chinle time. At the northwest end and off the flanks of the corridor, currents waned and lower energy environments prevailed. Furthermore, these flanking, more distal areas were more complexly interbedded.

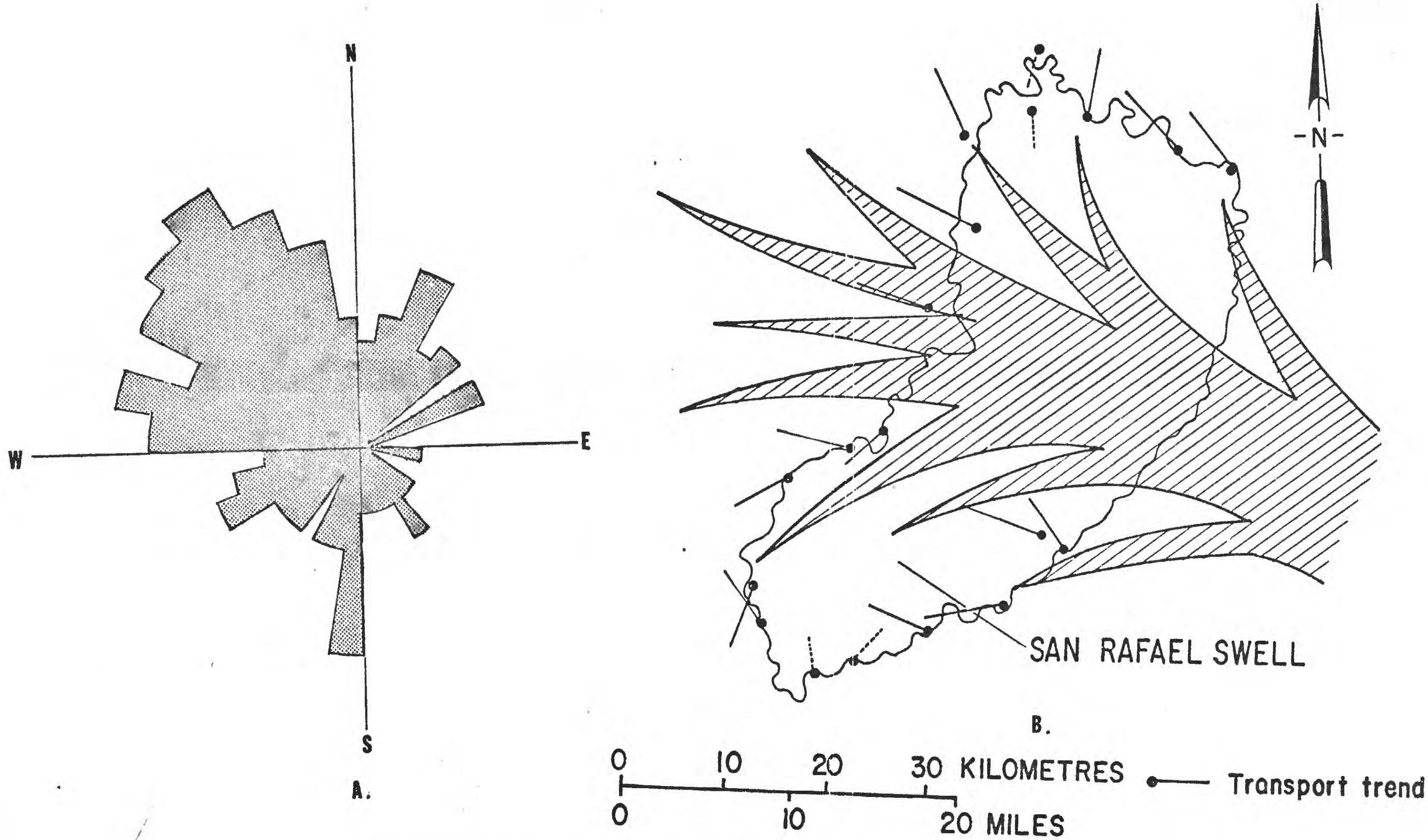


Figure 4.--Transport directions of the lower part of Sequence 1, Chinle Formation, San Rafael Swell, Utah. Equal-area rose diagram of the total of 130 measurements (A) and geographic distribution of transport trends (B). The patterned area suggests the flow dispersal pattern during deposition of lower Sequence 1.

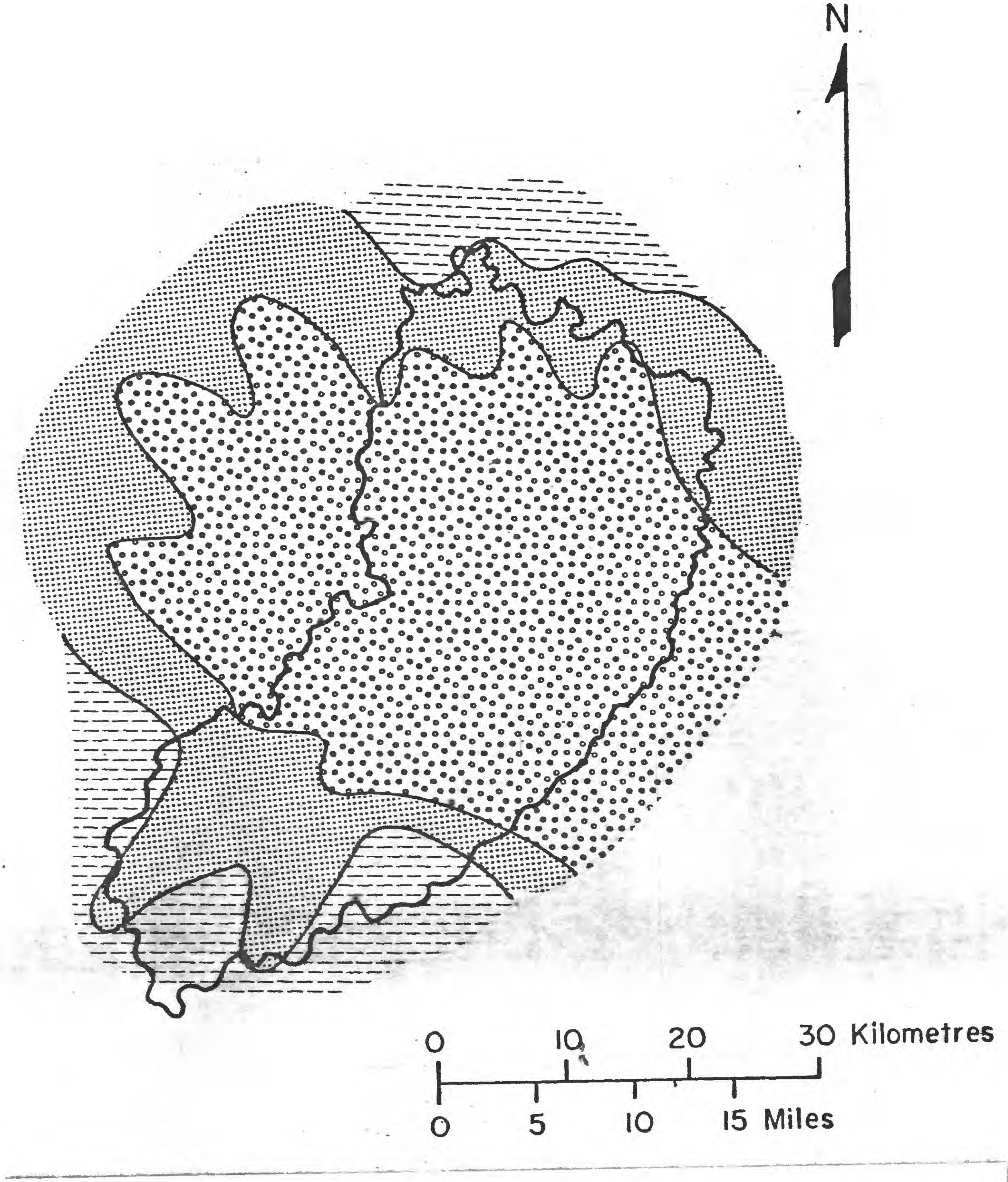


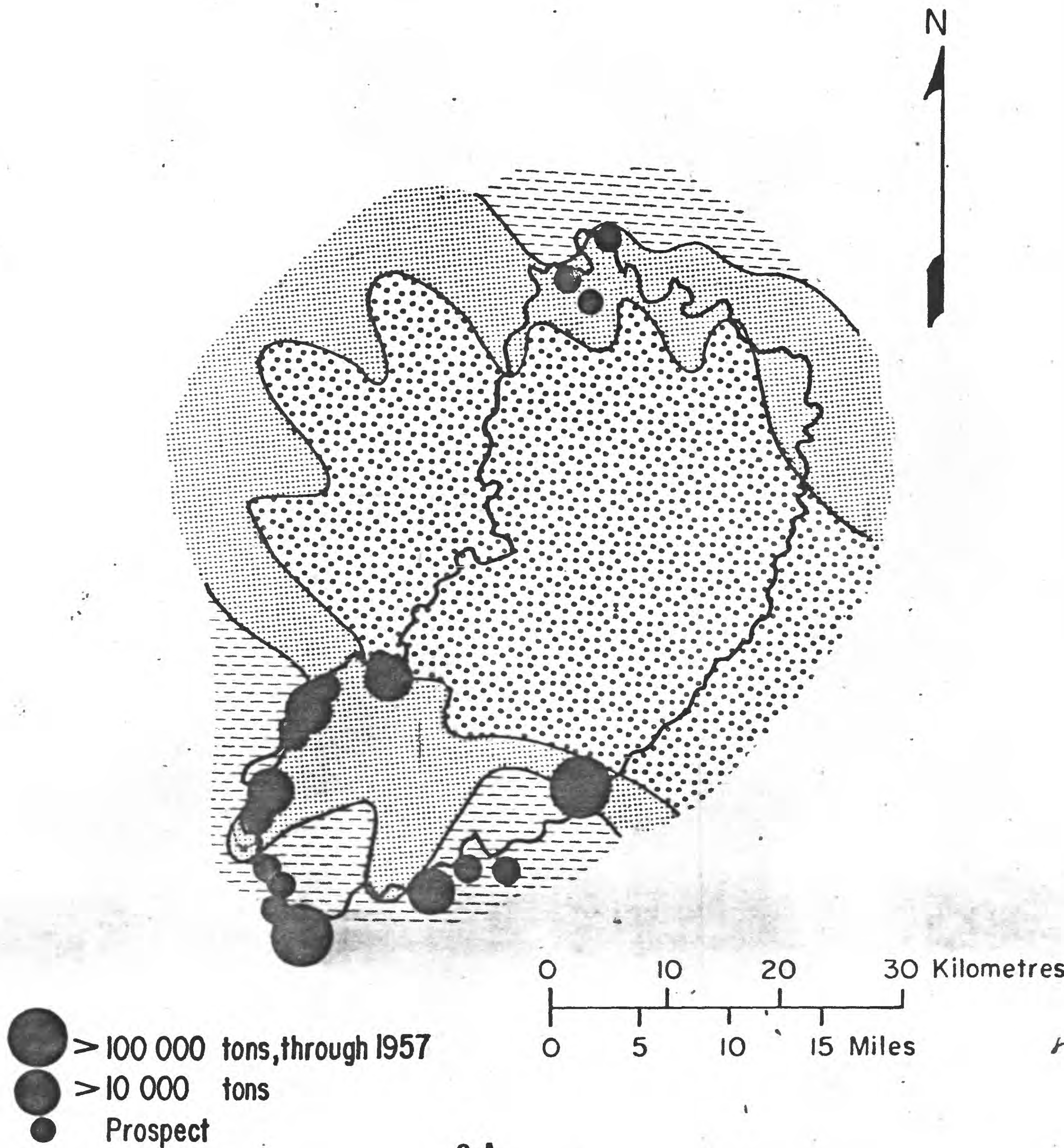
Figure 5.--Distribution of depositional environments, lower part of Sequence 1, Chinle Formation, San Rafael Swell, Utah.

Uranium

The distribution of uranium deposits in the San Rafael Swell is shown in figure 6. There is a close relationship between uranium deposits and the complexly interbedded, lower energy deposits; rocks in areas of uranium mineralization consist of sediment bodies of greatly contrasting textures which are interbedded on a relatively small scale. Apparently, interbedding of rocks of diverse textures influenced uranium mineralization, an inference supported by Fischer (1974), who felt that interbedded sandstones and mudstones were favorable host rocks. It is not known exactly what rock properties, be it hydrologic, geochemical, or mineralogical, influenced uranium mineralization.

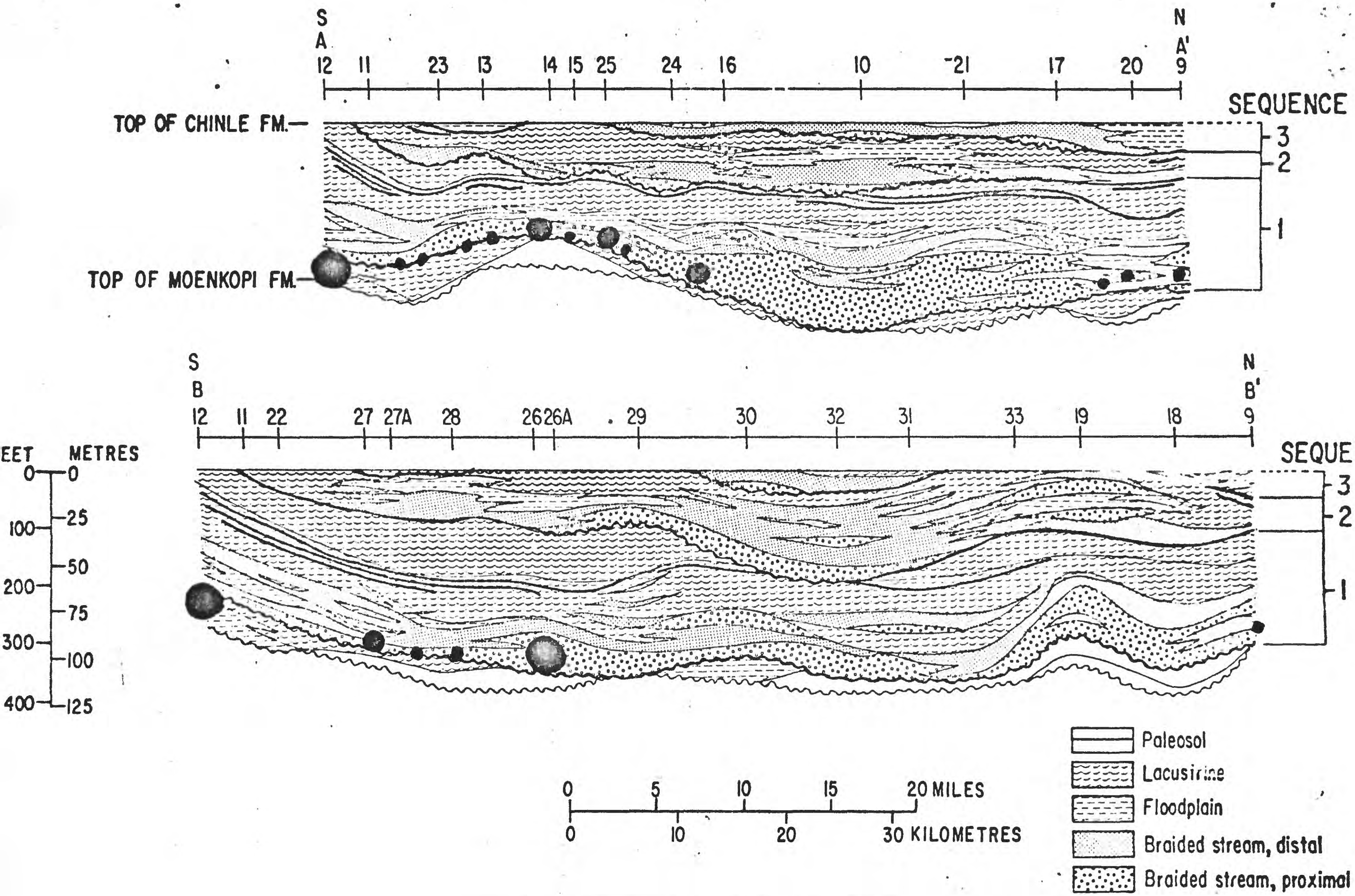
Areas favorable for uranium exploration

Favorable host rocks apparently exist in the subsurface off the north, west, and south margins of the Swell (fig. 7). This conclusion is based on the relationship between depositional environments and uranium. The areas to the north and the south are extensions of the deposits and environments shown on figure 6. The area to the west was also apparently an area of low energy environments, which is inferred from the distribution of environments and the change in transport trends during later Chinle time. During later Chinle time the distribution of environments contracted around an area in the east-central part of the Swell (fig. 8) such that low energy sediments were deposited on the higher energy sediments of the lower part of Sequence 1. This contraction accompanied a rotation of transport trends to the east (fig. 8), and was caused by a decrease in the energy level of the system (compare figures 5 and 8). By reversing this pattern of contraction back to the time of lower Sequence 1 in order to infer the distribution of environments in the covered area to the west, an area of low energy environments is predicted in the subsurface to the west.



6A.

Figure 6.--Areal (A) and stratigraphic (B) distribution of uranium deposits in the San Rafael Swell (data from Hawley, Robeck, and Dyer, 1968).


S
A
12
11
23
13
14
15
25
24
16
10
-21
17
20
N
A'
9
SEQUENCE
3
2
1
TOP OF CHINLE FM.
TOP OF MOENKOPI FM.
S
B
12
11
22
27
27A
28
26
26A
29
30
32
31
33
19
18
N
B'
9
FEET
METRES
0
100
200
300
400
0
25
50
75
100
125
Paleosol
Lacustrine
Floodplain
Braided stream, distal
Braided stream, proximal
0
5
10
15
20 MILES
0
10
20
30 KILOMETRES

6B.

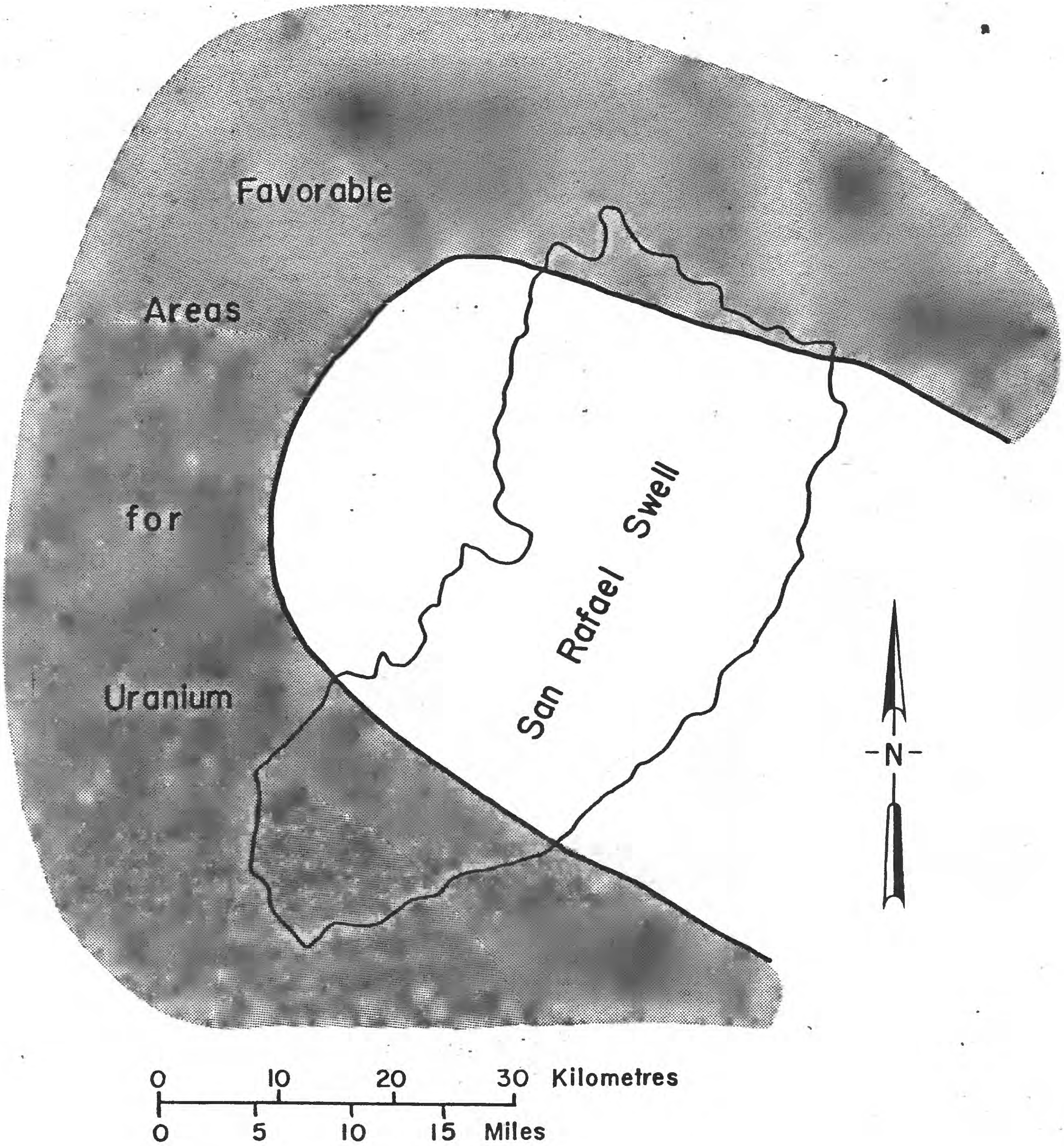
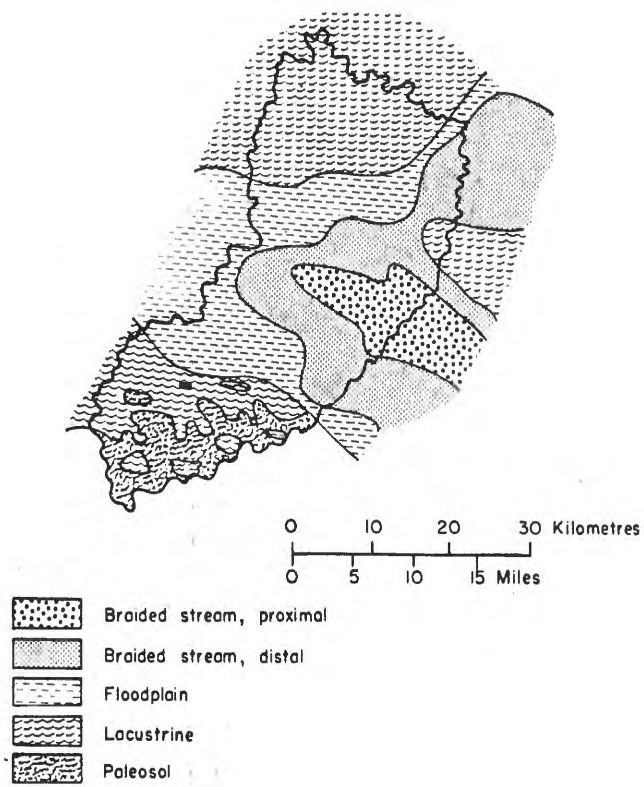


Figure 7.--Areas favorable for uranium exploration (patterned) in Chinle Formation, San Rafael Swell, Utah.



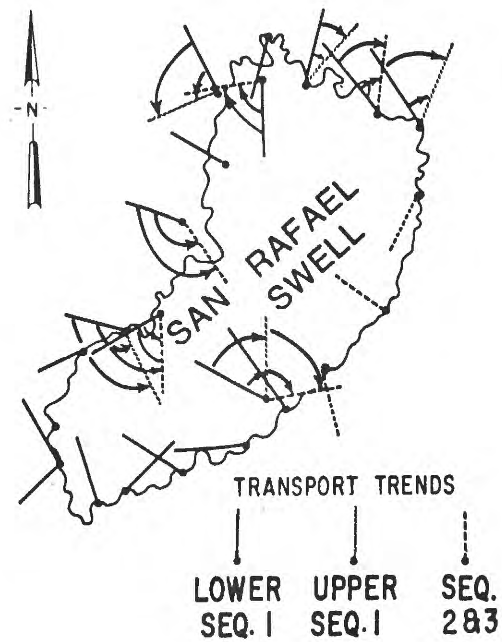


Figure 8.--Distribution of depositional environments, upper part of Sequence 1, Chinle Formation (A) and rotation of transport trends with time for the entire Chinle Formation (B), San Rafael Swell, Utah.

Other factors

The distribution of collapse features and the location of possible source rock may also have affected the localization of uranium in the Chinle in the San Rafael Swell. However, neither is an entirely satisfying relationship. The distribution of collapse features (fig. 9) does not explain the uranium deposits in the south end of the Swell where many uranium deposits are located. Hawley, Robeck, and Dyer (1968, p. 31) discuss this relationship more thoroughly. And if candidates for source rock are limited to volcaniclastic material within the Chinle, then the only source rock in the Swell would have been at the south end (fig. 10). Most uranium deposits have been found in the south, but there are also deposits in the north end where there is apparently no Chinle source material.

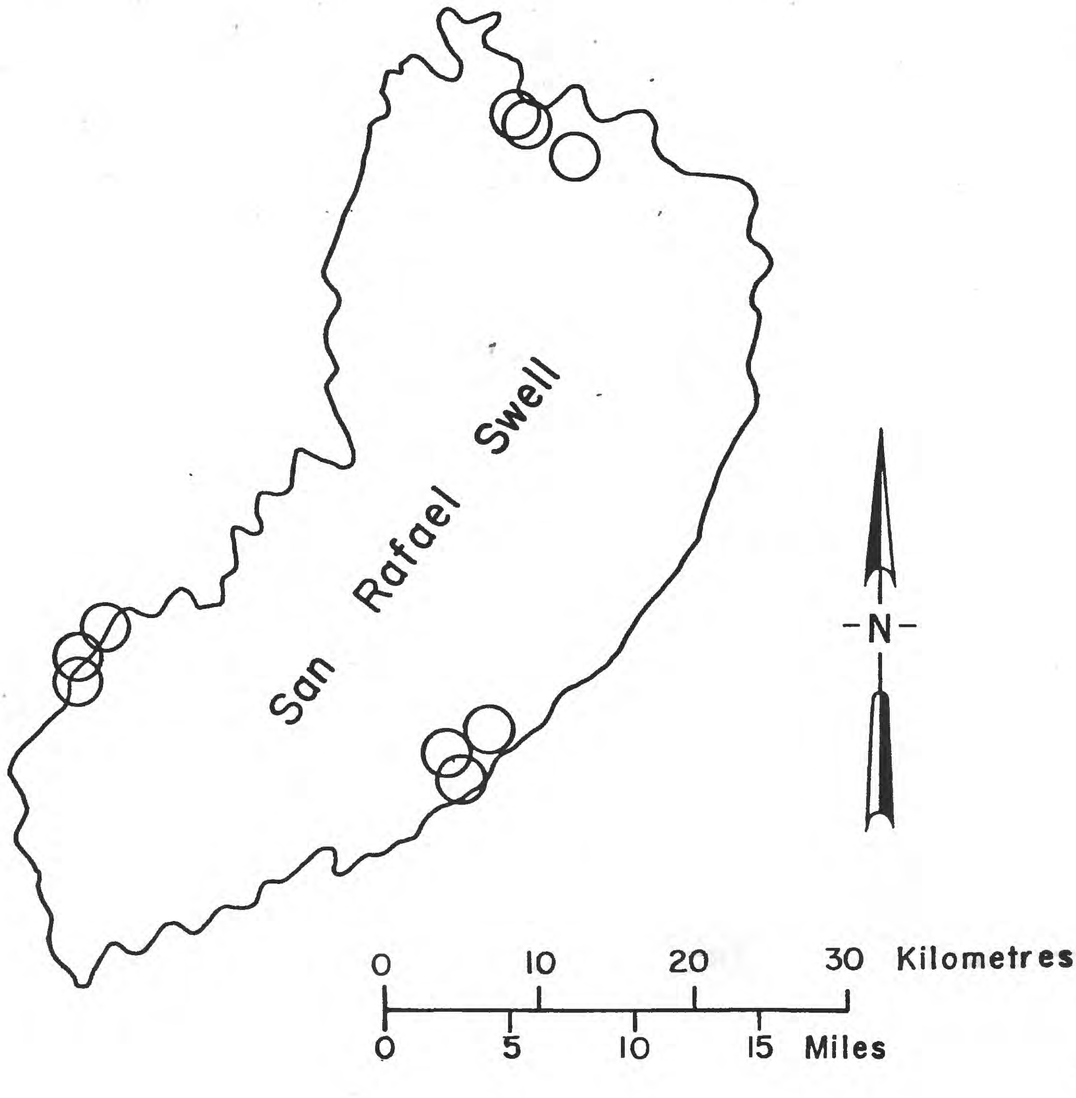


Figure 9.--Distribution of collapse features (circles), San Rafael Swell (from Hawley, Robeck, and Dyer, 1968).

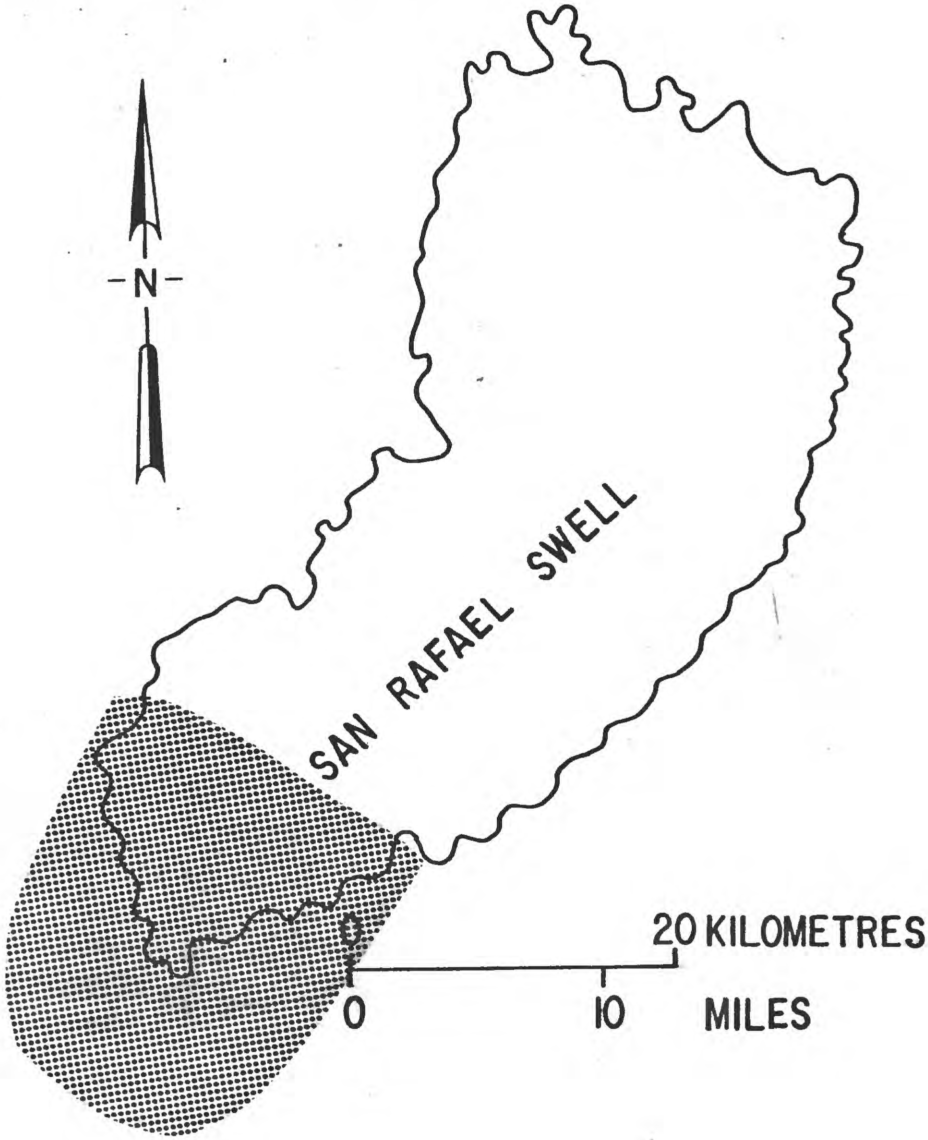


Figure 10.--Distribution of possible uranium source rocks in the Chinle Formation, San Rafael Swell.

Summary

A number of factors probably combined to influence uranium mineralization of Chinle rocks in the San Rafael Swell. One of these, the texture of the host rocks, resulted from processes operating in certain depositional environments. Therefore, by using depositional environments as a guide, areas favorable for uranium exploration may be selected.

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