CONF-811130--7

DEVELOPMENT TESTING OF GROUTING AND LINER TECHNOLOGY FOR HUMID SITES

MASTER

N. D. Vaughan
Environmental Sciences Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

ABSTRACT

Shallow land burial, although practiced for many years, has not always secured radionuclides from the biosphere in humid environments. To develop and demonstrate improved burial technology the Engineered Test Facility was implemented. An integral part of this experiment was site characterization, with geologic and hydrologic factors as major the components. Improved techniques for burial of low-level waste were developed and tested in the laboratory before being applied in the field. The two techniques studied were membrane trench liner and grouting void spaces.

INTRODUCTION

Shallow land burial as a disposal method for low-level radioactive wastes has been simple, cost-effective and practical for many years. In most cases the method involves digging a trench, emplacing the untreated waste, and covering with native soil. In humid environments, however, radionuclides have not always remained secure from the biosphere, as a result of water seeping into the trenches, soaking the waste, and mobilizing the radionuclides. Examples of radionuclide migration from trenches are at Oak Ridge National Laboratory, Maxey Flats, and West Valley (Dana et al., 1980; Jacobs, et al., 1980).

Although disposal in an arid climate is technically preferable, transportation costs and socio-political considerations prevent disposal of all low level radioactive waste at arid sites. Hence, improved methods of disposal are required at humid sites if radionuclide migration is to be minimized and costly remedial actions such as exhumation, repackaging, and reburial are to be avoided (Cutshall, 1980). To develop the necessary technology for disposal in humid areas the Engineered Test Facility (ETF) was implemented at Oak Ridge National Laboratory in solid waste storage area (SWSA) 6. Its major goal is to provide pilot-scale field data for evaluating the effectiveness of trench treatments in retarding radionuclide movement in humid areas. ETF will also aid in identifying the types and amounts of data necessary for adequate site characterization.

EXPERIMENTAL DESIGN

The design of the experiment requires nine trenches, three of which are used as controls, three are lined with a membrane, and three are grouted (Fig. 1). The trenches are on three meter centers and are nominally 3 m x 3 m x 3 m. Although they are small compared to standard operational trenches, they are never the less, in scale with the 0.3 ha site. Each treatment is assigned to a set of trenches based on a Latin Square design which eliminates any bias that might be introduced by trenches of differing depths. Thus each treatment occupies a row and a column that are unique, for example on the diagonal. A different chemical tracer is designated for each trench so when leakage begins the trench can be identified. Once all the trenches are filled and closed, four wells will be placed around each trench for monitoring the tracer movement.

For baseline studies prior to excavation ten 10-meter deep wells in a horseshoe configuration were drilled along with two 15 meter wells to the east and west of the horseshoe (ETF 11 and 12 in Fig. 1). The wells were used primarily for collecting groundwater data, but five of the wells were cored for geologic information. Two flumes and a rain gauge were also installed to measure surface hydrologic conditions.

SITE CHARACTERIZATION

An integral part of the experiment includes an hydrologic and geologic description of the ETF site. First to be the discussed will be geologic factors: stratigraphy, petrology, structure, geophysical aspects, and soils. The hydrologic factors include: precipitation, surface water occurrence and quality, ground water occurrence and quality, infiltration rates, and soil moisture.

Geologic Investigations

The Oak Ridge Reservation lies in the Ridge and Valley Province, which is characterized by alternating, elongate, northeast trending parallel ridges and valleys (McMaster, 1963). Differential erosion of the northeast striking Paleozoic strata has influenced, the parallel ridge-valley trend (Stockdale, 1951). These features are aligned with the major thrust faults in the Province. The area of interest is located in Melton Valley which is underlain by strata of the Middle to Late Cambrian Conasauga Group. Although the Conasauga Group generally underlies valleys throughout the region, it locally forms hillocks such as the one depicted in Figures 1 and 2.

The Conasauga Group is a very heterogeneous unit, consisting basically of alternating shaley limestones and limey shales. The six constituent formations, in ascending order are: Pumpkin Valley Shale, Rutledge Limestone, Rogersville Shale, Maryville Limestone, Nolichucky Shale, and Maynardville Limestone. It is the limestone members that are responsible for the hillocks as they are resistant to erosion. The ETF site is specifically underlain by the Maryville Limestone, a massive silty interclastic limestone interbedded with a dark gray mudstone (Haase and Vaughan, 1981).

The elevation to the top of the Maryville Limestone was determined from well drilling varies from 235 to 241 meters. The lowest elevations are at the southernmost end and rise to the 238 meter level which runs approximately along the line delineated by wells ETF 12 to ETF 11. A knoll of Maryville Limestone is situated by well ETF 2 and rises to an elevation of 241 meters. Toward the northwest the elevation falls to 236 meters. The top of the Maryville Limestone shows a distinct east-west alignment, which is not reflected in the north-south orientation of the surface topography.

Upon excavation the knoll of bedrock near well ETF 2 was revealed to be a tight anticlinal fold (Fig. 3). The axis of this fold was traced across the middle three trenches (trenches 4, 5, and 6 in Fig. 1). The northern limb of the anticline dips away from the center to the northwest at between 44° and 52° while the other limb dips to the southeast at between 47° and 70°. In Figure 4 the fracture patterns in the rocks on the limbs are shown. Between the rectangular slabs of rocks and the more massive units are fractures, resulting from tensional stresses. Immense deformation in the core of the anticline further fracturing the rock is evident. Finally, openings created by alternating bands of rock and soil are noted. It is these fractures and openings that are responsible for carrying the water.

Another anticlinal fold was traced from the lower left hand corner of Trench 1 to the upper right hand corner of Trench 3. The northern limb dips northwest at between 32° and 57° while the southern limb dips southeast at between 28° and 56°.

These two anticlines are drag folds resulting from the deformation caused by the thrust faults which were mobilized during the Appalachian Orogeny. The folds are widespread features and can be observed in most trenches in SWSA 6. Shallow seismic surveys identified the first anticline, and shallow resistivity surveys found the top to the bedrock which was verified later by drilling.

Soil samples were obtained from trench walls to construct a soil profile for the site. As expected the soils derived from as heterogeneous formation as the Maryville are themselves varied. Soils ranged from weathered siltstone and sandstone to a silty or sandy loam. The siltstone-sandstone component is a result of the carbonate being leached from the parent rock. This mechanism gives the soil a shaley appearance and has led over the years to the misnomer "Conasauga Shale". Soil pH ranges from 4.2 to 5.2 and is always acidic, in contrast to typical caclareous soils which exhibit pH's in the range of 7.2 to 8.2. Some of the horizons have particles coated with manganese and iron oxides, and when distribution coefficient (Kd) ^{85}Sr was determined it was these layers that had the highest values (sample VIIc in Table 1).

Hydrologic Investigations

The water level for the area was monitored in the wells. While the water table fluctuates, it always has an east-west trend which coincides with that of the structure of the Maryville. As might be expected the water table is highest at the northern end of the hillock and lowest at the southern end. Since the period has been dry, the water table level between 238 and 237 meters is considered low. The rain gauge (Fig. 1) measured only 897 mm of precipitation over the past year instead of the normal 1430 mm (NOAA, 1980). When it does rain, some of the wells have a delayed response of a few hours.

A pump test using well ETF 12 showed a drawdown lineation that ran from well ETF 12 through wells ETF 9 and ETF 1 to include ETF 2, with a saddle point at ETF 9 (Fig. 1). This lineation coincides with the anticlinal fold found in the middle row of trenches, and lends support to the concept that the fractures and overall structure are controlling water flow in the area. Other pump tests showed the range of transmissivities to be between 0.8 and 25.0 m^2/d and storage coefficients to be between 3.9×10^{-7} and 2.8×10^{-2}. Again these support the concept of fractured flow from a field standpoint and agree well with the results of a fracture model by Sledz and Huff (1981).

Tracer tests were performed by investigators from University of Arizona and Indiana University under subcontract to ORNL. New tracers were used by the groups along with established ones to further the art of ground water tracing. Fluorocarbon tracers were used by the investigators from Indiana University. These tracers are highly desirable because they have minimal sorption properties, are essentially non-toxic, and have no natural background component so that small amounts may be used (Cooper, 1981).

The fluorocarbons were injected in the well ETF 1 (Fig. 1) and arrived before they were anticipated based on calculation and previous studies of the area. The calculated rate of movement for the fluorocarbons was 1 to 2 m/d. An even more startling result was initial location of the tracer arrival; in wells ETF 2, ETF 3, ETF 7, and ETF 8. The expected result was a first arrival at ETF 6. The conceptual model derived from the results is the tracer moved along a line between wells ETF 2 and ETF 3, and wells ETF 7 and ETF 8. Another line was also described from the results and includes wells ETF 4, ETF 5, ETF 9, and ETF 10. A plausible reason for this unexpected result was found by examining at fracture patterns in the Conasauga Group. These patterns are related to major structural elements in the area such as the Copper Creek Fault, a thrust fault, and a major fold (Sledz and Huff, 1981). The tracer results fall along the fracture pattern with its major control described as the Copper Creek Fault (Cooper, 1981). This finding provides more evidence that the ground water flow at the site is structurally controlled.

Water quality data have been gathered on a quarterly basis and Table 2 lists selected results. The major cation is calcium and the major anions are silicate and sulfate. Water quality was also performed on the water collected at the flumes. The only surprising result was a ^3H level at 10^3 Bq/l at the flume abutting the rest of SWSA 6. This is the level normally found in burial ground wells. This suggests that the waste trenches are releasing ^3H to the draw which drains the area. Neither the other flume nor the ETF wells had ^3H levels above detectable levels. As a result of low precipitation, soil moisture measurements were not readily availabile. During the first seven hours of an infiltration test the water flowed at 41.6 m^3/d attesting to the ability of the fractures to move water.

TREATMENTS

The treatments for this experiment are intended to retard water movement and reduce trench subsidence both of which are problems with aging trenches. A membrane or liner was chosen to retard the water movement into the trench, and a grout was developed to halt trench subsidence.

These treatments were developed by laboratory experiments involving aquaria filled with a synthetic waste mixture in proportions of buried low level waste (Fowler, et al., 1973). The waste was placed in the aquaria trenches approximating the burial mode used at ORNL (Fig. 5). For the first laboratory experiment only native soil was used to backfill the aquarium; a standard practice in burial grounds. Water was poured on the top and collected at the base of the trench. The trench was then flooded with a 7% bentonite suspension from below (Fig. 5). The suspension filled the voids between the waste and some of interstices between the soil particles. Water was again introduced, and only milliliters of water were recovered instead of liters of water noted before flooding; a decrease in water flow of approximately two-orders of magnitude was achieved.

The second experiment also involved an aquarium filled with waste, but backfilled with a bentonite (15% by weight) and shale mixture (Fig. 6), which is the same proportions as the bentonite seals used at ORNL. Water was poured on top of the trench, and the first liter ponded on top (Fig. 6). Although this mixture retards water movement, the dryfill did not pack into the voids between the waste. Only when this trench was flooded from below with a 7% bentonite suspension was water retardation of the same order of magnitude achieved as noted above.

From these two experiments it was decided that the fill would have to be a wet grout in order to achieve the void occlusion required. Also a membrane of bentonite could be used. The membrane was applied on the top of the second trench and exhibited good strength and flexibility. With several wettings it did not dislodge nor did it lose its elasticity.

Three grout mixtures were studied in detailed before selecting one composed of cement, fly ash and bentonite. A 7% bentonite suspension was considered first. However, during pumping into the aquaria, it lifted the top covering. Due to possible problems of floating waste in the trench this suspension was rejected. Another mixture was 0.1 M MgCl and 10% $NaSiO_2$ solution. Because the precipitate formed only filled part of the void and the remaining liquid filled the rest, this mixture was not chosen. Furthermore, neither of these mixtures possess the desired rigidity to prevent trench collapse. Finally, a cement, fly ash and bentonite mixture produced a pumpable slurry that filled the voids with solid material when set, and provided the rigidity desired (Sealand, per. comm.). This was a variation of a grout already used by ORNL (Tamura, per. com.). The grout will be flooded into the trench from the top while the membrane, 1.27 cm thick, will be sprayed on the walls of the trenches.

ACKNOWLEDGMENTS

Research sponsored by the Office of Waste Management, U.S. Department of Energy under contract W-7405-eng-26 with Union Carbide Corporation. Publication No. 1876, Environmental Sciences Division, ORNL.

REFERENCES

1. Cooper, W. T., 1981, Groundwater Tracing Tests with Multiple Organic Solutes at the Engineering Test Facility, SWDA6, Oak Ridge National Laboratory, Tennessee, Report, Subcontract 7031.

2. Cutshall, N. H., 1980, Burial Ground Technology in Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1979 Auerbach, S. I. (compiler), ORNL-5620.

3. Dana, R. H. Jr., V. S. Rogan, S. A. Molello, H. H. Bailey, R. H. Fiiokies, C. G., R. H. Fakudiny, V. C. Hoffman, 1980. Genral Investigation of Radionuclide Retention in Migration Pathways at the Wast Valley, New York Low-Level Burial Site. NUREG/CR-1565. 140pp.

4. Fowler, E. B., J. L. Warren, K. A. Pashman, J. W. Healy, 1973, Transuranic Waste Research and Development Program, LA-5281-MS, 26 pp.

5. Haase, C. S. and N. D. Vaughan, 1981, Stratigraphy and Lithology of the Conasauga Group in the Vicinity of Oak Ridge, Tennessee, (abs.) in Abstracts with Programs, The Geological Society of America 30th Annual Meeting, Southeastern Section, v. 13, n. 1, p. 8.

6. Jacobs, D. G., J. S. Epler, R. R. Rose, 1980, Identification of Technical Problems Encountered in the Shallow Land Burial of Low-Level Radioactive Wastes, ORNL/SUB-80/13619/1, 180 pp.

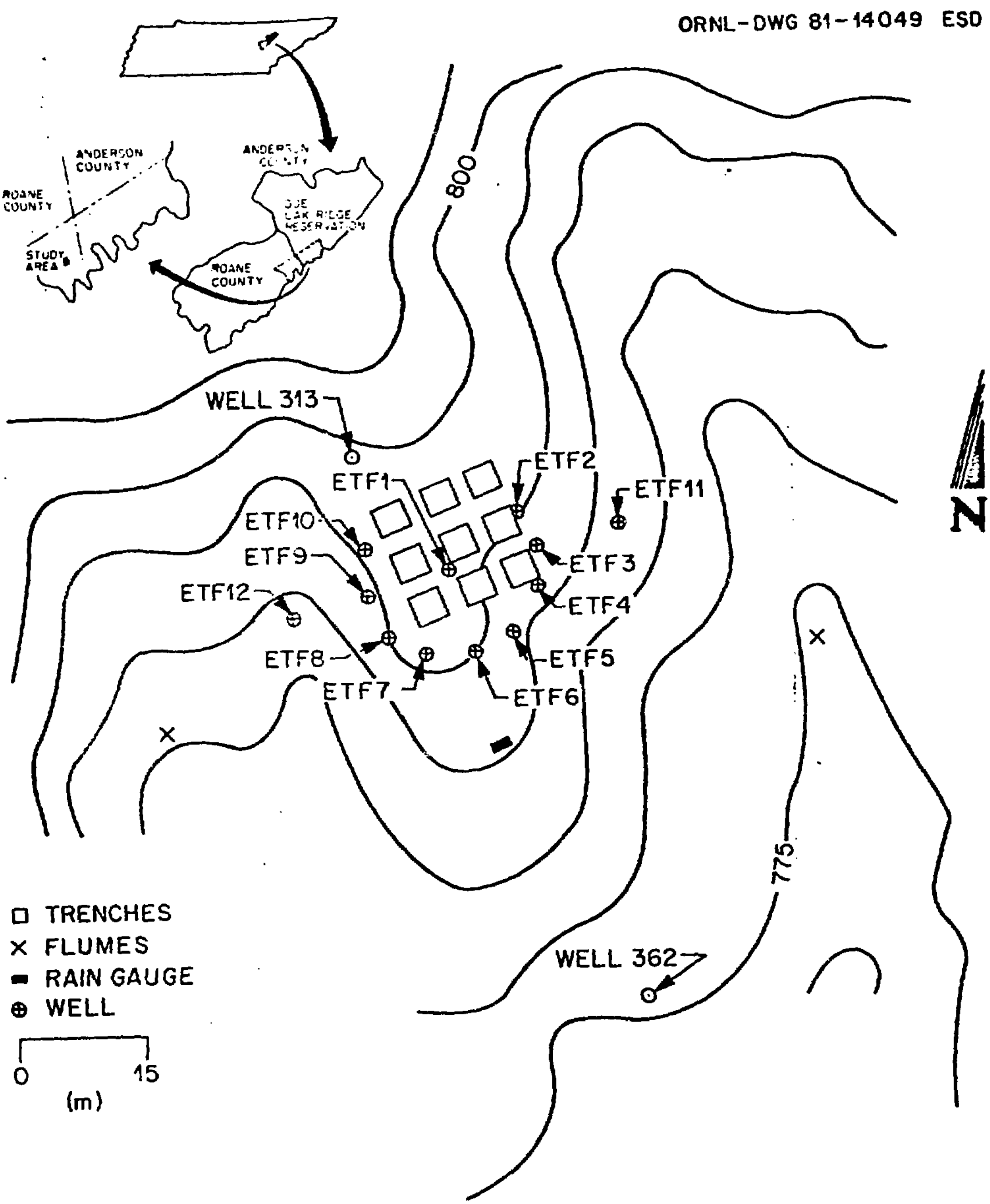
7. McMaster, W. M., 1963, Geologic Map of the Oak Ridge Reservation, Tennessee: U.S. Atomic Energy Commission ORNL-TM-713, 23 pp.

8. NOAA, 1980, Local Climatological Data, Annual Summary with Comparative Data, Oak Ridge, Tennessee, National Climatic Center, Ashville, NC.

9. Sledz, J. J. and D. D. Huff, 1981, Computer Model for Determining Fracture Porosity and Permeability in the Conasauga Group, Oak Ridge National Laboratory, Tennessee, ORNL/TM-7695, 138 pp.

FIGURE LIST

Fig 1



ORNL-DWG 81-14049 ESD
ANDERSON COUNTY
ROANE COUNTY
STUDY AREA
ROANE COUNTY
800
775
WELL 313
WELL 362
ETF1
ETF2
ETF3
ETF4
ETF5
ETF6
ETF7
ETF8
ETF9
ETF10
ETF11
ETF12
N
TRENCHES
FLUMES
RAIN GAUGE
WELL
0
15
(m)

Fig 2

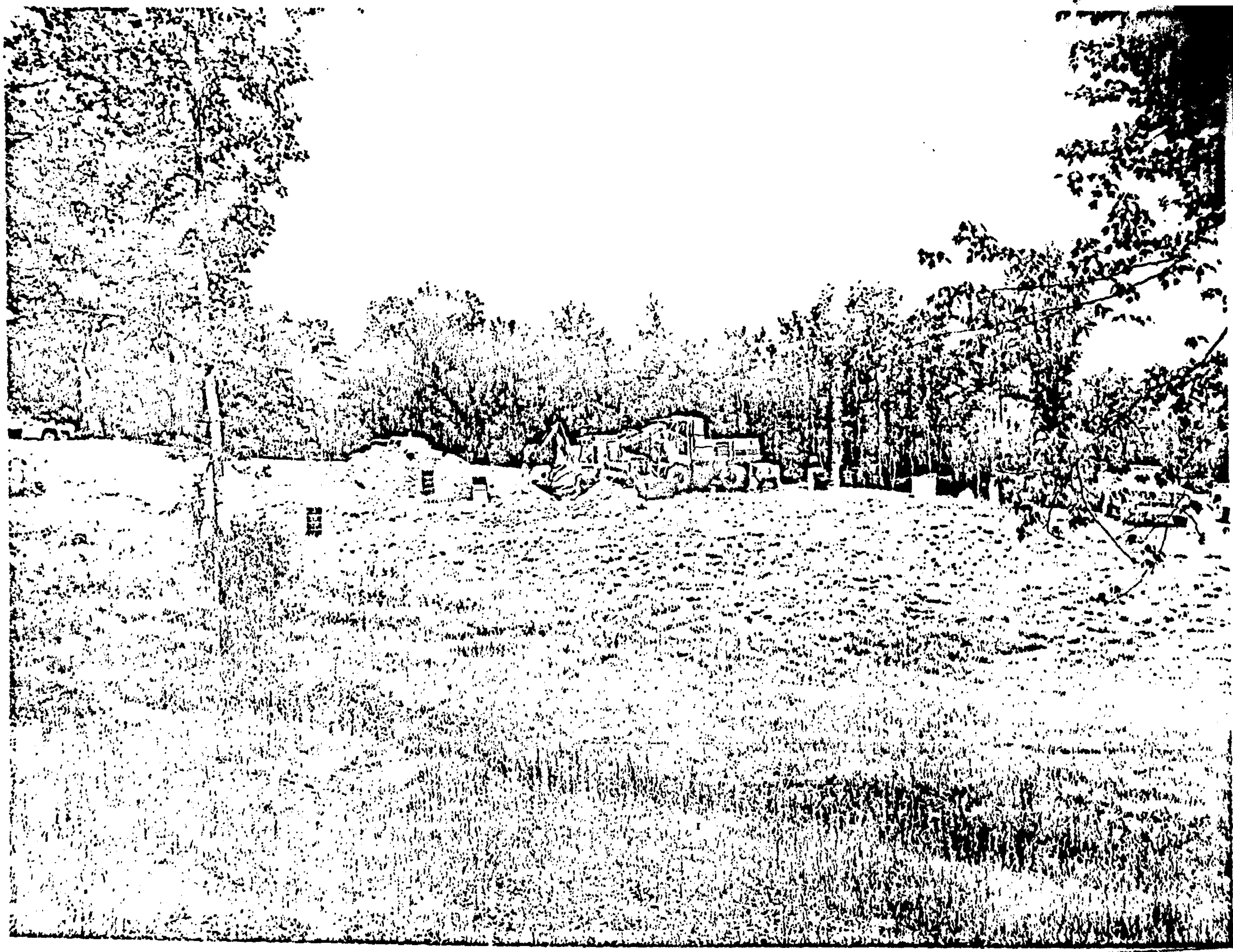


Fig 3

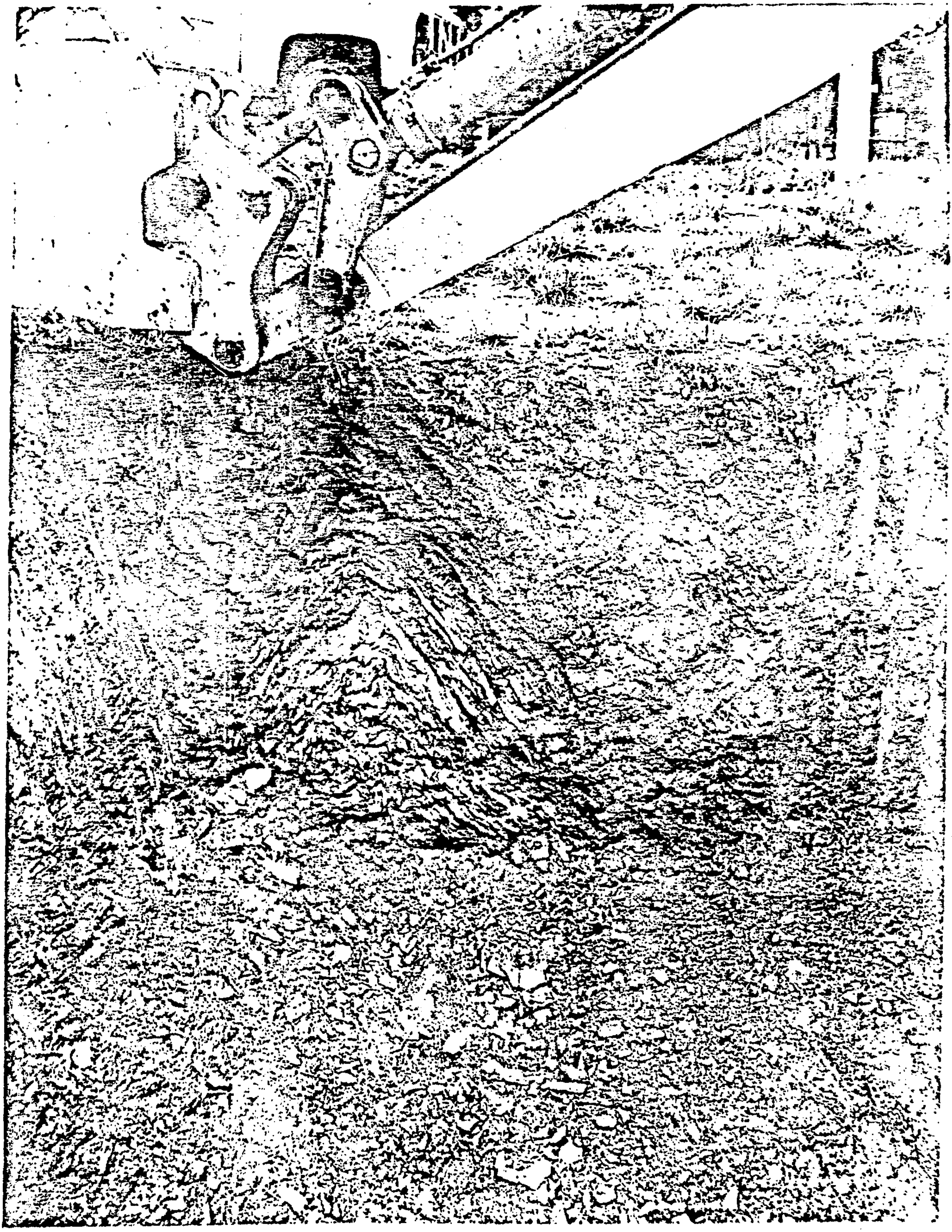
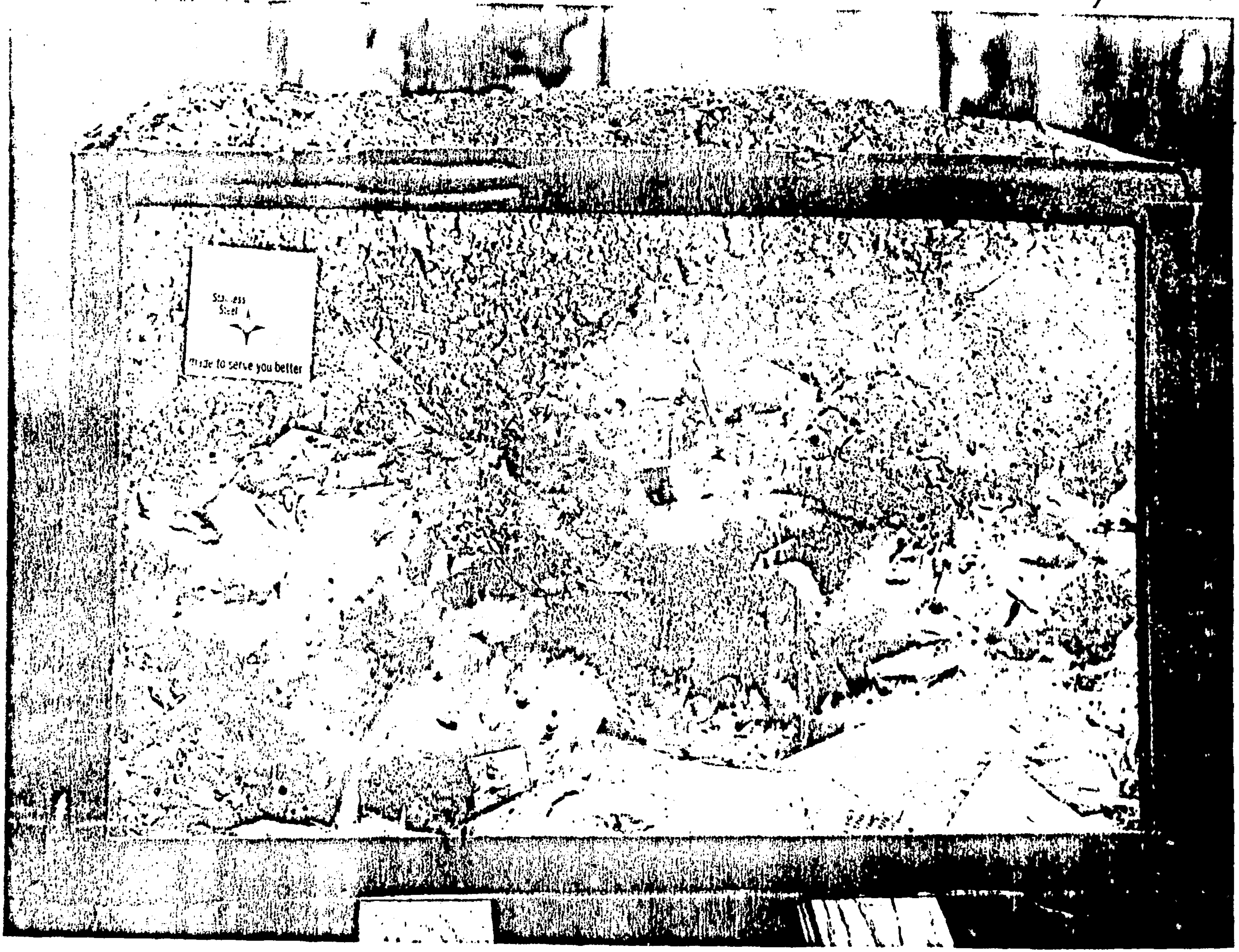


Fig 5



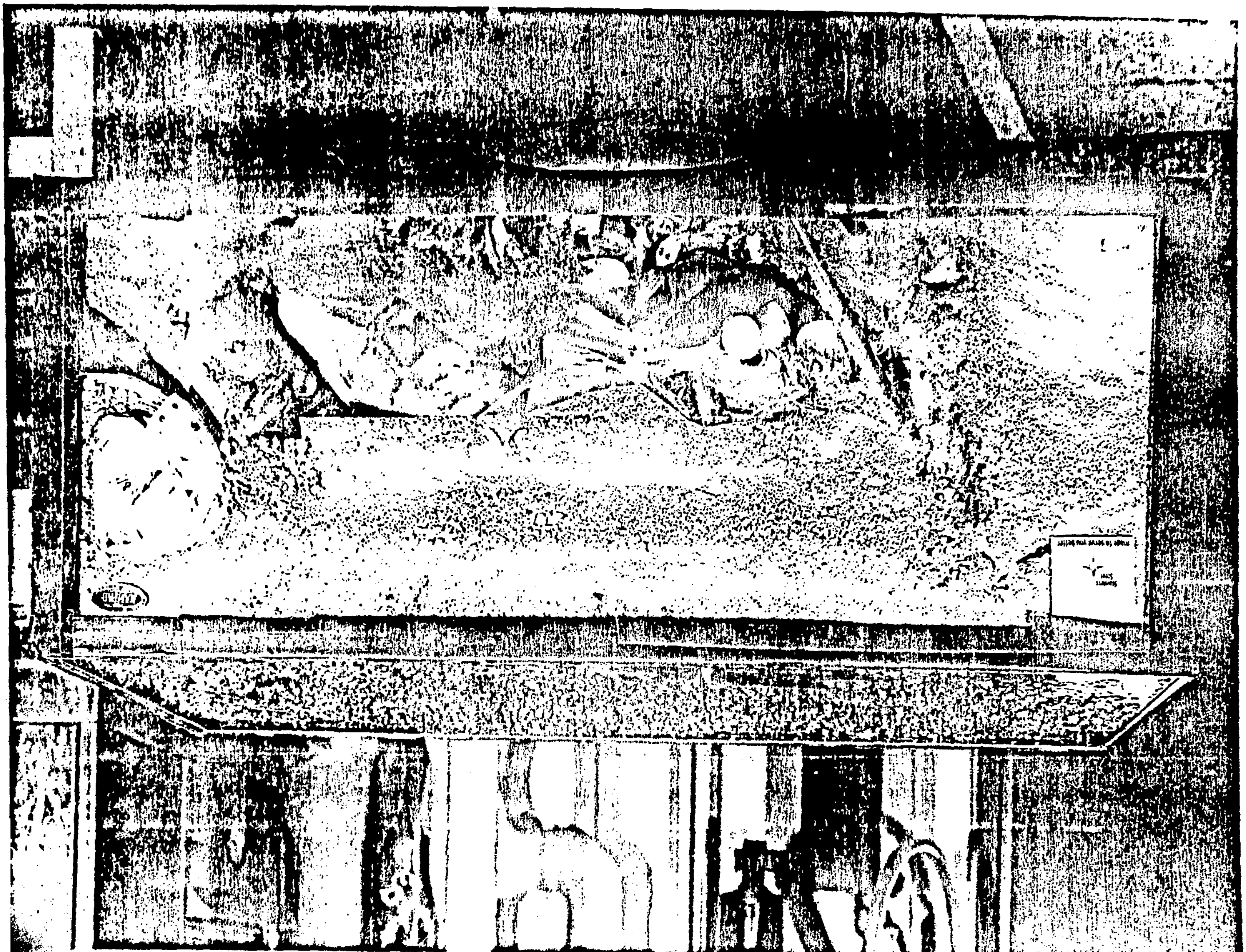


Fig 6

Table 1

Profile Description

Profile Sketch	Horizon and Depth (in cm)	Description of Horizon	Kd
A	0-5.1	Brown (7.5 YR 4/6) silt loam; medium to coarse granular structure; moderate friable; pH = 4.8; many fine roots; smooth boundary.	2.9
B	5.1-12.7	Finely laminated dull yellow orange (10 YR 7/2) and dark brown (10 YR 3/2) weathered siltstone; very coarse platy rock structure; pH = 5.0; few roots; smooth boundary.	3.4
IIC	12.7-22.9	Dull orange (10 YR 7/4); weathered sandstone; very coarse platy rock structure; pH = 4.7; clay and iron oxide coating; few roots.	1.5
IIIC	22.9-27.9	Finely laminated dull yellow orange (10 YR 7/2) and dark brown (10 YR 3/3); weathered siltstone; very coarse platy rock structure; pH 4.7; brown and brownish black iron and manganese coating; few roots.	4.6
IVC	25.4-38.1	Brown (7.5 YR 4/4); silt loam; moderate, medium coarse granular structure; weathered platy siltstone fragments; firm; pH = 4.9; Fe & Mn coatings.	7.0
VC	38.1-66.0	About same as IIIC; pH = 4.7.	7.3
VIC	66.0-86.4	Dark, reddish brown (5 YR 3/4); other features are the same as IVC; pH = 4.9.	5.9
VIIC	86.4-96.5	Finely laminated dull yellow-orange (10 YR 6/3) and brownish black (10 YR 2/2) slightly weathered siltstone; very coarse platy rock structure; pH = 5.2; heavy manganese coatings.	16.8
R1	96.5-130.0	Slightly weathered, undull.	0.8
R2	130.0^+		

Table 2

Water Quality of ETF Wells

Well (ETF)	1	2	3	4	5	6	7	8	9	10	11	12
ions (μg/ml)												
Ca	49.0	37.0	28.3	30.0	39.0	43.0	36.0	39.0	41.0	27.8	49.0	31.0
Na	2.84	2.49	1.98	2.10	2.60	3.23	2.50	2.40	5.18	2.09	3.53	2.60
Fe	0.14	0.16	0.043	0.180	0.023	0.15	0.88	0.33	0.097	0.068	0.029	0.037
Al	0.021	0.018	0.019	0.028	0.022	0.019	0.039	0.017	0.015	0.26	0.014	0.019
Sr	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	10.1	<0.1
Mg	3.86	3.90	2.42	2.56	2.60	3.82	2.90	3.20	6.30	3.38	7.40	3.40
K	0.67	0.91	0.51	0.55	0.54	0.92	0.66	0.76	1.08	0.51	0.93	1.11
Mn (ng/ml)	6.9	201	8.2	7.2	9.0	56.0	17.0	11.0	41.0	2.20	66.0	2.20
SiO_2 (μg/ml)	14.4	14.2	10.5	15.6	14.0	13.3	13.7	13.3	9.3	14.0	15.7	15.1
SO_4	5.12	4.42	9.78	9.8	6.36	6.50	6.18	8.18	13.6	3.92	11.2	6.44
Cl	0.56	0.48	2.18	2.56	1.39	1.92	1.48	1.28	1.76	0.64	2.60	1.26
F	0.05	0.05	0.17	0.08	0.05	0.17	0.07	0.05	0.17	0.07	0.19	0.10