# LOCATION OF SITES
# FOR
# HAZARDOUS WASTE REPOSITORIES
# IN IOWA

## PHASE 1: GEOLOGICAL RECONNAISSANCE MAPPING
## PROGRESS REPORT 1

by

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**Open File Report**

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Hazardous wastes are those wastes or combination of wastes that, because of its quantity, concentration, biological degradation, leaching from precipitate, or physical, chemical, or infectious characteristics, has either of the following effects:

1. Causes, or significantly contributes to an increase in mortality or an increase in serious, irreversible, or incapacitating reversible illness.
2. Poses a substantial danger to human health or the environment.[1]

To safely reposit hazardous wastes two fundamental site requirements must be satisfied:

1. Isolation of the wastes from the environment, especially from present or potential future surface or groundwater resources.
2. A secure location protected from vandalism or other human interaction.

Other additional factors that are important in the choice of a repository site and its engineering include:

1. A site location with minimum susceptibility to violation of its integrity by catastrophic geological processes.
2. Some inherent ability of the site materials to detoxify or otherwise neutralize the adverse properties of the wastes.
3. The ability to recover selected wastes for reprocessing or further detoxification.
4. Proximity of the site to a transportation system adequate to allow safe movement of the wastes from their points of origin.

Many hazardous wastes may be safely contained in specially modified repositories not unlike county landfills. Others may require more extreme considerations for safe storage. This study will address only the location of safe repositories for those wastes which prove to be the most hazardous and only the geological considerations in their location and not detailed engineering, logistical, or cultural considerations.

## Waste Burial Techniques

In Iowa the most effective technique for removal of hazardous wastes from the environment is to bury them in a suitable geological unit. There are three primary burial storage techniques; bored storage, trench storage, and cavern storage.

### Bored Storage

The bored storage technique involves the boring of a series of large diameter holes into the geologic storage formation. This procedure allows the tailoring of each hole (lining, chemical additives, etc.) to suit the specific waste to be stored in it. The hole would then be sealed with a cap of concrete or other suitable material.[2] With this technique incompatible wastes can be isolated.

Trench Storage

For trench or pit storage, an open trench is excavated for storage of the wastes. The wastes would be covered by materials sufficient to preclude the downward movement of water into the stored waste. This procedure is the most efficient method of disposal of large volumes of waste.

Cavern Storage

This technique includes the excavation and engineering of a cavern for storage of the wastes. While the most expensive of the three techniques, cavern storage has several advantages over the other two techniques. Unlike other techniques, the cavern remains open (is not filled and compacted) and it is much easier to keep the storage area dry and thus reduce the possibility of waste interaction with the environment. Cavern storage also allows monitoring of the wastes to detect deterioration of storage containers as well as providing easy access for retrieval or reprocessing, if desired.

## Treatment of Waste Prior to Storage

Because of the potential for adverse effects on the environment by hazardous wastes at any storage site, no matter how carefully it may be designed, a maximum effort should be undertaken to detoxify and especially to reduce the volume of the wastes prior to storage. A 1977 NIACC study[3] estimated that over 632,000 tons of hazardous waste was generated in Iowa every year. The volume of this waste is 35 million gallons, a volume so great that, as indicated by the study, if these wastes were placed in 55 gallon drums, and the drums were placed side by side, they would line the entire boundary of the state of Iowa, and its northern boundary twice.

Many techniques are available to achieve volume reduction and reduced toxicities. The toxicity of most organic and many inorganic wastes can be safely reduced in properly designed high temperature incineration facilities. The establishment of such facilities would greatly reduce the volume and toxicity of many wastes and therefore increase the safety factor for long-term storage.

## Geological Storage Units

The rock types which appear to be the most acceptable for the storage of hazardous wastes in Iowa are shales and overconsolidated and basal tills. These rocks have low permeabilities and high clay content.

The low permeabilities of these shales and tills impede the movement of water and liquid wastes. Some of the shale units have permeabilities as low as .001 feet/year. Till permeabilities as low as 0.5 feet/year[4] are not uncommon.

### Shale Units

The shale units to be examined as potential storage sites for hazardous wastes are primarily Paleozoic in age. These include shales of the Brainard Shale Member of the Maquoketa Shale Formation, the Juniper Hill Shale Member of the Lime Creek Formation, the Sheffield Formation, the Maple Mill Formation, and several shale formations in rocks of Pennsylvanian age, especially in the Des Moines Series. The Carlile Formation is the youngest shale unit to be examined.

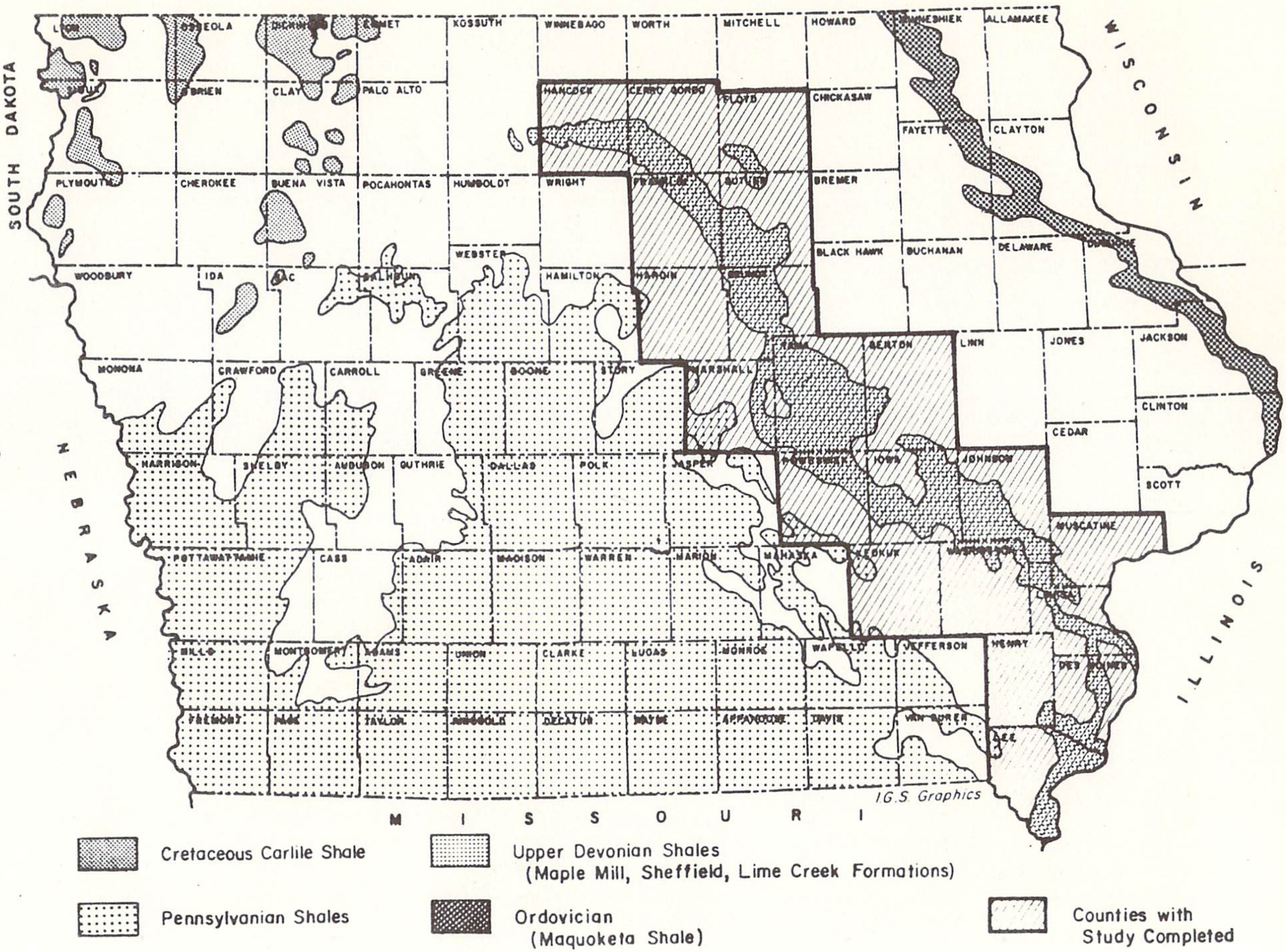
Table 1: IOWA STRATIGRAPHIC COLUMN

| ERA | SYSTEM | SERIES | UNIT TO BE STUDIED |
|---|---|---|---|
| Cenozoic | Quaternary | Pleistocene | "Till" |
| Mesozoic | Cretaceous | | Carlile Fm. |
| | Jurassic | | |
| Paleozoic | Pennsylvanian | | "various shales" |
| | Mississippian | | |
| | Devonian | Upper | Maple Mill Fm. |
| | | | Sheffield Fm. |
| | | | Lime Creek Fm. |
| | | Middle | |
| | Silurian | | |
| | Ordovician | | Maquoketa Shale Fm. |
| | Cambrian | | |
| | Precambrian | | |

Table 1 reviews the Iowa stratigraphic column and the shale units to be examined. Figure 1 displays the areal limits for consideration of storage sites in each unit.

The till units to be considered in Iowa include basal tills of the Des Moines Lobe of Wisconsinan age and Lake Michigan Lobe of Illinoian age, as well as overconsolidated Pre-Illinoian tills which overlie the previously discussed shale units, especially the Pennsylvanian and the Carlile Formation.

Figure 1. Hazardous Waste Storage Study
- Possible Geologic Containers -



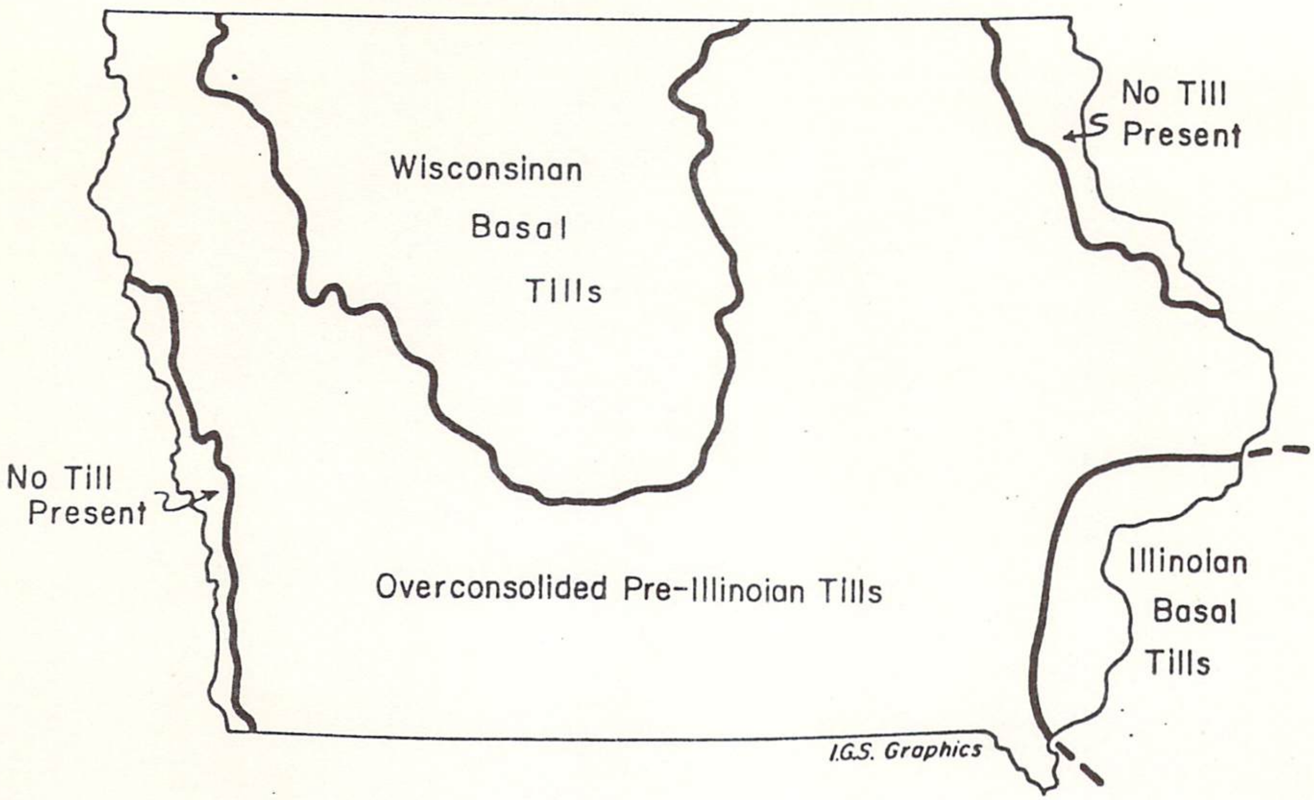



Figure 2. Till Units to be Examined for Hazardous Waste Storage

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Brainard Shale Member

The Brainard Shale is the uppermost of the four members which comprise the Maquoketa Formation. It is a blue to bluish-gray shale with some interbedded limestone layers near the top and bottom of the unit.[5] It's thickness is widely variable, ranging from 0 to more than 160 feet.[6] The dominant clay mineral in the Brainard is illite.

Because the Brainard Shale Member is an easily erodable unit which outcrops in an area of pronounced bedrock erosion, it is seldom found as bedrock except at the base of the Silurian escarpment. In this location it is commonly capped by several hundred feet of dolomite and is inaccessible for bored or trench storage techniques. Caverns could, however, be excavated into the shale at these localities, and the Brainard will be examined for areas suitable for this method of storage.

Upper Devonian Shales

The character and stratigraphic relationships of the Upper Devonian shales to be considered for hazardous waste storage are quite variable over the area of their outcrop belt. The three shale units of interest, Lime Creek, Sheffield, and Maple Mill (from oldest and stratigraphically lowest to youngest), are separated by limestones and dolomites in north-central Iowa, but form a continuous and commonly undifferentiable shale unit in the southeast portion of the state (see Figure 3).

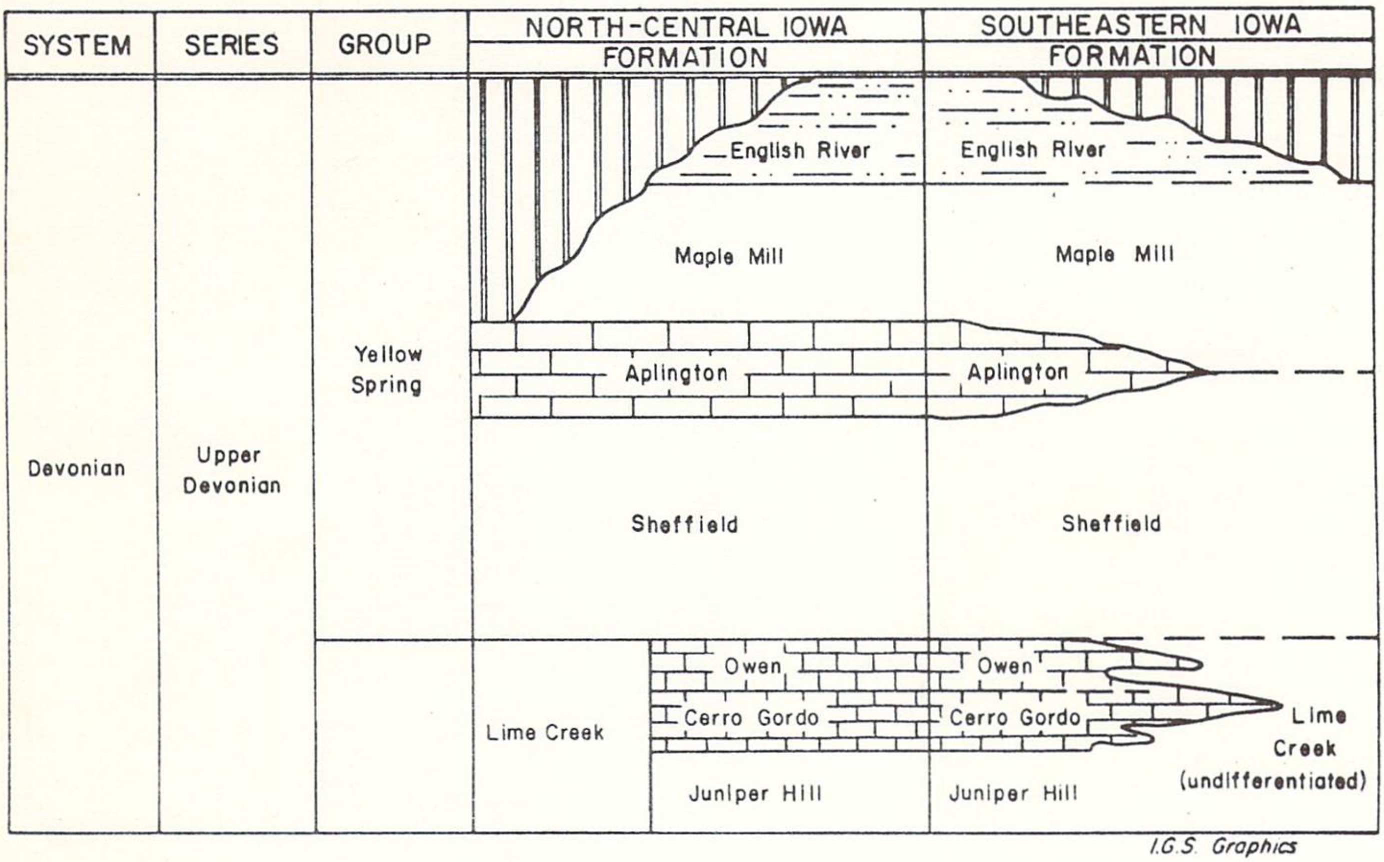



Figure 3. Stratigraphic Relationship of Upper Devonian Shales, North-Central to Southeast Iowa.

These shales reach thicknesses of 45 feet (Maple Mill), 75 feet (Sheffield) and 45 feet (Juniper Hill) at Union in Hardin County. The shales thicken to maximums of 150 feet (Maple Mill in central Washington County), 175 feet (Sheffield in southern Washington and northern Henry Counties) and over 100 feet (Juniper Hill in south-central Butler County). The formations form a continuous unit over 365 feet in thickness near North English in Keokuk County and over 285 feet at Burlington.

Pennsylvanian

Sediments deposited in Iowa during Pennsylvanian time represent multiple fluctuations of the level of the seas that once covered the central interior of North America (see Figure 1). These repeated fluctuations of the sea level led to the deposition of over 50 individual shale units in the state. The anoxic sea floor condition present at many times in the Pennsylvanian led to deposition of black shales commonly containing small amounts of arsenic, lead, copper, uranium, thorium, vanadium, zinc, cadmium, chromiun, nickel sulfides and other potentially toxic materials which are especially hazardous due to their mobility in the acidic groundwater which is common in Pennsylvanian rocks. The presence of these toxic materials and other naturally occurring compounds renders the water unsuitable for drinking in many areas.

Hazardous wastes may be stored by several methods in these rocks. Certain of the thicker shale units may be suitable for bored or trench storage. Also, an abandoned underground coal mine could be engineered for storage of especially hazardous wastes that may require monitoring. The engineering required to prepare an underground coal mine as a hazardous waste repository would be extensive. Because an unattended mine deteriorates rapidly, the required engineering must be commenced during or immediately upon cessation of the mining. One proposal by Dr. Matthew Avcin, Chief of the Iowa Geological Survey's Coal Division, would include the erection of a corrugated steel Quonset-type structure in the mine, and grouting of the area between the structure and the mine walls (see Figure 4). This would insure the integrity of the mine roof. The floor would then be sealed with concrete to minimize water problems. Waste stored at such a facility

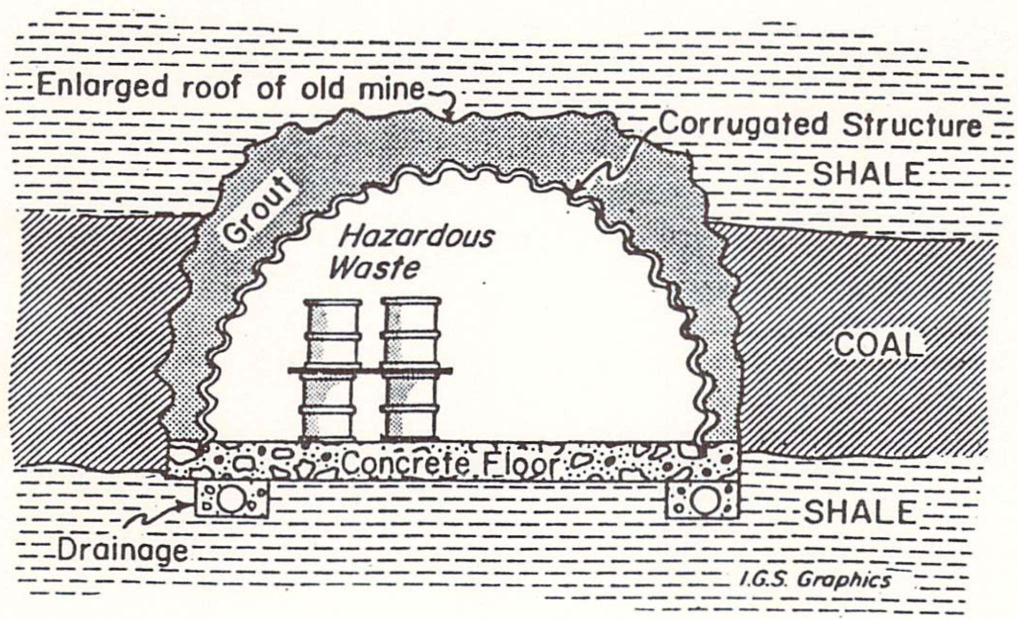



Figure 4. One Design for Storage of Hazardous Waste in an Abandoned Coal Mine

could be remotely monitored using a television system and easily retrieved or maintained if necessary, and isolation of incompatible wastes in individual rooms would be possible.

## Carlile Formation

Very little is known about the distribution or characteristics of the Cretaceous Carlile Formation in Iowa. It occurs in outcrop at only a few locations along the Big Sioux River in northern Plymouth and southern

Sioux Counties and in about 20 wells in northwestern Iowa. The unit is a silty shale and has a known maximum thickness of 75 feet. The northwest quarter of the state is characterized by thick unconsolidated materials (locally in excess of 600 feet) which may render storage of hazardous waste in this unit impractical. The area of Carlile bedrock is presently being studied as a part of the Iowa Geological Survey's Northwest Iowa Water Resources Study, and more information on the Carlile should be available by Fall of 1980.

## Till Units

### Overconsolidated Nebraskan and Kansan Tills

Classically the Pleistocene of Iowa has been divided into four stages (from oldest to youngest) Nebraskan, Kansan, Illinoian, and Wisconsinan (see Table 2). Deposits of these stages are composed primarily of glacial drift.

Table 2: PLEISTOCENE STRATIGRAPHY IN IOWA

| | "Classic Nomenclature" | Present Nomenclature |
|---|---|---|
| Series | Stage | Stage |
| Pleistocene | Wisconsinan | Wisconsinan |
| | Illinoian | Illinoian |
| | Kansan | Pre-Illinoian |
| | Nebraskan | |

Recent studies, however, have shown that the classic Kansan and Nebraskan are composed of materials from at least six glacial ice advances and that classic Kansan and Nebraskan stratigraphy is very complex. Until the details of these ice advances can be accurately identified, the Iowa Geological Survey is referring to classic Kansan and Nebraskan deposits as pre-Illinoian.

Glacial drift is a general term which refers to all materials immediately derived from glaciers. Of these materials, till (the material deposited directly from ice and not transported by wind or water) is the most common in Iowa. Till is a mixture of materials of many lithologies and sizes (boulders to clay) eroded from the land surface by advancing ice. The material is abraded, weathered, and redeposited as a unit which can possess homogeneous characteristics over a wide area. A pre-existing till unit that is overridden by a subsequent ice advance is greatly compacted by the weight of the overlying ice. After retreat of the ice, the original till remains tightly compacted and is referred to as overconsolidated. Subsequent erosive forces have exposed several overconsolidated tills in the area of pre-Illinoian deposits. Storage of hazardous waste in these tills would be by the bored or trench storage method, with the quantity and type of waste which could be safely disposed at any site limited by the characteristics of the till unit at the site. Storage in such an overconsolidated till unit overlying one of the previously discussed shale units, especially Pennsylvanian shales, seems to hold the most promise for safe and expeditious storage of many hazardous wastes.

Basal Till Units

Till deposits can be subdivided into two major categories based on the mode of their deposition; ablation tills and basal tills. Ablation tills are materials which have been deposited on or in front of glacial ice and have abundant interbedded and stratified lenses of sand, silt and gravel.

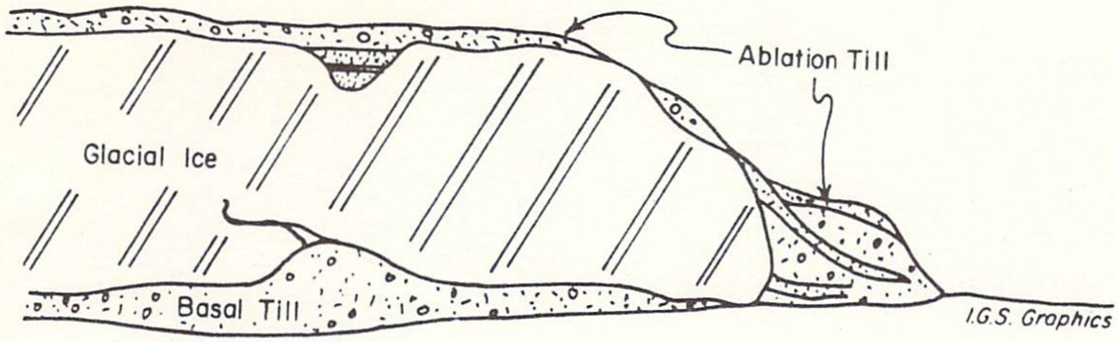



Figure 5. Modes of Formation of Ablation and Basal Tills.

These lenses provide highly permeable conduits for the rapid movement of fluids and are therefore unsuitable for containment of hazardous wastes. Basal tills are deposited at the base of a glacier and are very homogeneous with no interbedding or high permeability lenses. Basal tills are also overconsolidated due to their subglacial origin and are therefore well suited for hazardous waste disposal. Basal till units have been identified in deposits of Wisconsinan (north-central Iowa) and Illinoian (southeast Iowa) stages. These basal till units are locally suitable for the storage of some hazardous wastes. The suitability of basal tills for such storage at any site will be dependent on the characteristics of the till at that location. Bored or trench storage techniques could be utilized for hazardous waste disposal in basal tills.

One advantage of tills over the shale units for the disposal of hazardous wastes is the mineralogy of the tills. While Iowa's shale units are composed almost entirely of illite clays, the tills are rich in kaolinite and montmorillonite clays. The calcium and sodium ions in the till clays are easily mobilized making the clays receptive to cation exchange. They will adsorb many hazardous leachates which may migrate from storage sites, thus providing an additional safety factor.

## Method of Investigation

### Shale Units

The three factors considered in the geological reconnaissance mapping of an area for hazardous waste storage in shales are 1) the thickness of the unconsolidated materials over an area, 2) the thickness of the consolidated rocks overlying the shale unit and 3) the thickness of the shale unit. A series of seven maps of each area are being constructed which will be used to identify specific areas for detailed on-site evaluation. The interaction of these maps to produce the final map of potential storage sites is displayed in Figure 6.

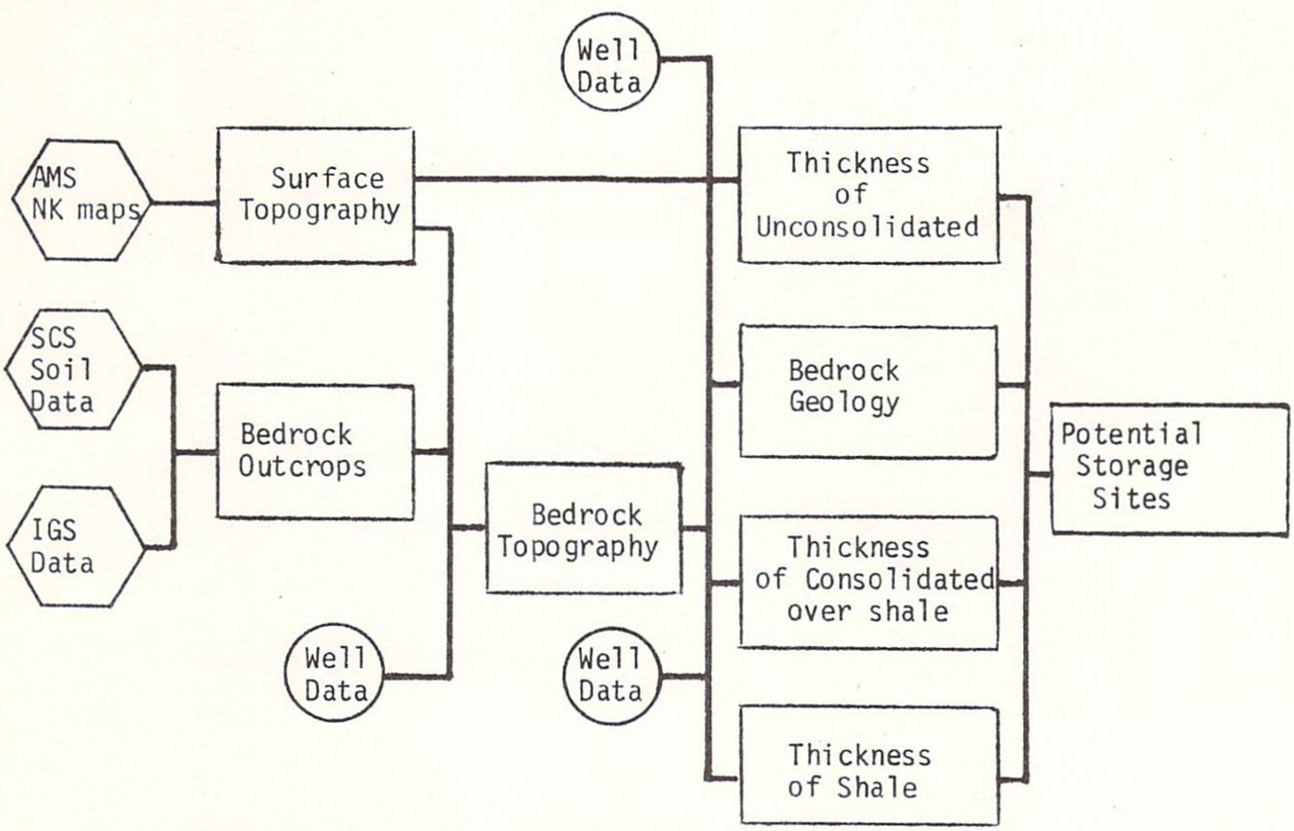
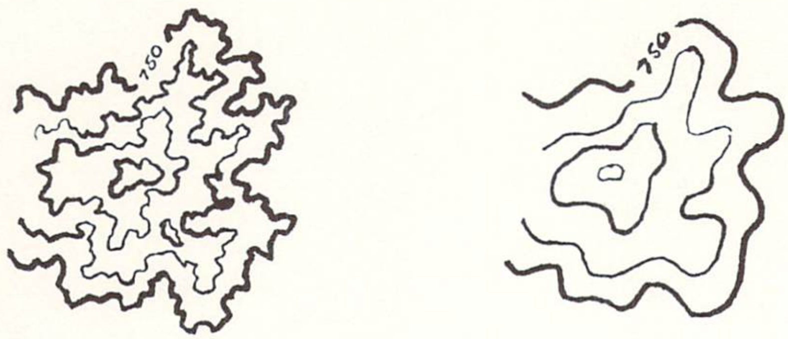



Figure 6. Flow Diagram for Production of Map of Potential Storage Sites.

Map of Surface Topography - A map of surface topography is created by generalizing the contours as published on the 1:250,000 scale, U.S. Geological Survey topographic maps. This generalizing is accomplished by the manual smoothing of the contours as shown in Figure 7. The generalization makes




original USGS Contours generalized contours

Figure 7. Generalization of U.S. Geological Survey 1:250,000 scale Topographic Maps.

the contours more compatible with the other maps used in the study.

Map of Bedrock Outcrops - The map of bedrock outcrops is compiled by combining data on outcrops presently in the Iowa Geological Survey data files with information taken from U.S. Soil Conservation Service (SCS) County Soil Survey Reports. The SCS reports not only identify outcrops, but also soils which are underlain by bedrock at a depth of 5 feet or less (considered to outcrop for this study).

Map of Bedrock Topography - By combining outcrop locations and their elevations from the map of surface topography with the elevation of bedrock known at other locations from IGS data, such as well records, maps of the topography of the bedrock surface are created. These maps may be entirely new or revisions of pre-existing maps.

Map of Thickness of Unconsolidated Materials - Well data, which provides point values for the thickness of unconsolidated materials, is combined with information derived from the maps of surface and bedrock topography to create this map. With the well data for control points, values for the unconsolidated thickness are obtained by subtracting the bedrock elevation of any location from its surface elevation (the thickness of the material between the surface and bedrock). This map provides controls for the first of the three reconnaissance mapping factors.

Map of Bedrock Geology - To identify the location of the shale units of interest a map of the bedrock geology must be created. This is done by combining known bedrock geology from well and outcrop studies with the map of bedrock topography.

Map of Thickness of Consolidated Material Overlying the Shale Unit - This map is created by combining points where the thickness of consolidated material overlying the shale unit of interest is known, such as wells and outcrops, with data from the map of bedrock topography. The map provides data for the second of the major factors for the geological reconnaissance mapping.

Thickness of Shale Unit - The final major factor is obtained by creating a map of the thickness of the shale unit under study. This map is produced using well and outcrop information in addition to the bedrock topography map in those areas where the shale is the bedrock unit.

Map of Potential Sites for Hazardous Waste Storage - The ultimate goal of the production of the seven maps just described is the identification of those areas which should be examined in detail as potential sites for Hazardous Waste Storage. Economics will be the primary factor governing the maximum thickness of consolidated and unconsolidated materials above a potential storage target. However, the potential hazards produced by migration of wastes into the overlying units must also be considered.

The characteristics of the wastes (toxicity, solubility, cation interaction, and a host of other properties) and the shale (its permeability, mineralogy, lateral continuity, etc. as well as its proximity to aquifers), will be considered in choosing a minimum allowable shale thickness at a potential storage site. It is possible that a site might prove suitable for the safe storage of one type of waste, but not another. Once these three parameters have been determined, the identification of suitable sites is a matter of identifying those areas which fit the criteria. Each site would then require detailed geologic and hydrologic evaluation including extensive test drilling before it could be judged suitable for storage.

Till Units

The evaluation of the suitability of till units for hazardous waste storage has not yet begun and the techniques to be employed have not been determined. Among those factors that will be considered are the thickness, mineralogy, permeability and lateral continuity of the till unit, the thickness and nature of overlying materials, the proximity to paleosols and aquifers, and the nature of the local bedrock.

## Conclusions

The initial phases of the geological reconnaissance of consolidated (shale) and unconsolidated (till) material in Iowa indicates that reasonably safe repositories for most hazardous wastes can be identified in Iowa. Facilities for bored, trenched, or cavern storage of these wastes can probably be established in all quadrants of the state. The exact location of sites for these materials, the nature of the materials which may be safely stored, and the engineering requirements must be determined on a site specific basis. The most important consideration in the determination of a site's suitability for storage of a hazardous waste must be the potential impact on the local environments, especially water resources.

## References Cited


(1) from Iowa House File 719, 68th General Assembly, 1979, page 2.

(2) Tuthill, S. J., Gordon, D. L., and Dorheim, F. H., 1972: Hydrogeologic Considerations in Solid Waste storage in Iowa, Public Information Circular No. 4, Iowa Geological Survey, pp. 40-41.

(3) Pierce, D. R., 1977: Hazardous Substances and Pesticide Survey and Training Program, Volume 1, North Iowa Area Community College, Mason City, Iowa.

(4) Kunkle, G. R., 1968: A Hydrogeologic Study of the Ground-Water Reservoirs Contributing Base Runoff to Four Mile Creek, East-Central Iowa, U.S.G.S. Water Supply Paper 1839-0, page 036.

(5) Ladd, H. S., 1928: The Stratigraphy and Paleontology of the Maquoketa Shale of Iowa, Part I, IGS Annual Report XXXIV, page 329.

(6) Parker, M. C., 1971: The Maquoketa Formation (Upper Ordovician) in Iowa, Misc. Map Series I, Iowa Geological Survey.