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INVENTORY OF KARST SUBSIDENCE IN THE VALLEY AND RIDGE PROVINCE OF EAST TENNESSEE

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ABSTRACT

The first regional inventory of karst activity in the Valley and Ridge Province of East Tennessee was performed as a part of ongoing studies at Oak Ridge National Laboratory pertaining to environmental impact assessment of waste disposal in karst settings. More than half the land area in the Valley and Ridge Province of East Tennessee is underlain by karst-prone carbonate bedrock. The regional karst inventory was initiated to obtain current information on the extent of active karst subsidence in the region for use in decision making by the Department of Energy in planning future waste disposal facilities at Oak Ridge, Tennessee.

The inventory was performed by contacting personnel of federal, state, and county agencies to obtain reports of known active karst subsidence within the region. Data from these interviews were tabulated resulting in identification of more than 250 karst subsidence incidents in East Tennessee, most of which have occurred since 1980. Although the information obtained was largely anecdotal, approximate location, date, size, and circumstances under which the collapses occurred were recorded for as many cases as could be documented.

The study also included detailed reconnaissance of selected areas similar in geology and hydrology to a study area at Oak Ridge, Tennessee to identify causative factors which contribute to karst subsidence in the region and for comparison of the occurrence of visible karst features at different sites. Human activities affecting site hydrology such as large scale land clearing and earthmoving projects were related to most of the subsidence incidents inventoried.

Introduction

Since about 1981 studies have been performed by the Department of Energy (DOE) at Oak Ridge, Tennessee to evaluate the potential use of thick residual soils for development of waste disposal facilities. The soils under investigation are those which form upon weathering of the Copper Ridge and Chepultepec dolomites, the lower formations of the Knox Group. The residual soils are attractive as waste disposal media because depth to the aquifer ranges from about 50 to 90 feet (15 to 27 m) beneath ridge crests, and soils are readily workable with conventional earth moving equipment. Within East Tennessee, the formations of the Lower Knox Group have by far the thickest soils and greatest depths to water. Since these soils are associated with a weathered carbonate bedrock parent material having karst development, uncertainties regarding the likelihood of karst subsidence and resultant uncertainties in future site performance have delayed development of a proposed low-level waste disposal facility on such a site.

Studies performed between about 1981 and 1984 focused on selection of sites potentially feasible for development and on geologic and geohydrologic site characterization. The difficulty in performance assessment of a karst site has stimulated the performance of this regional inventory of karst activity in the Valley and Ridge Province of East Tennessee, as well as performance of soil mechanical analysis of thick residual soils which occur locally within the region (Ketelle et al. 1987). The principal reason for performing such an inventory is to develop a database which can be used to describe the amount of karst subsidence within the region and typical dimensions of subsidence features. Since no central organization monitors subsidence activity in Tennessee, this inventory is the first regional scale data compilation of karst subsidence for the study region.

Subsequent to completion of the inventory and database compilation, site reconnaissance was performed at a site similar to the Oak Ridge setting but having active subsidence. This site reconnaissance study was performed to document the causes and frequency of subsidence which may accompany site development. The availability of regional and local data documenting the degree of karst activity enables development of realistic scenarios including the subsidence mechanism for use in site performance analysis.

Technical Approach

The karst inventory study for the Valley and Ridge Province in East Tennessee was performed in two phases. Phase I included data collection over the total region, and Phase II consisted of performing detailed reconnaissance of a site geologically and topographically similar to a study site at Oak Ridge.

Activities in Phase I included acquiring available data from files of the U.S. Geologic Survey obtained from a recent investigation of sinkhole occurrence in the eastern United States (Newton, 1986). Additional data for East Tennessee were acquired by contacting federal, state, county, and local agencies which would be likely to know of subsidence occurrence at the regional and local scale. Municipal or other local officials were contacted only when officials at the county level designated them as specific sources of information.

In this inventory, information sources were limited to those sources mentioned due to economic and schedule constraints. Agency representatives were contacted by telephone to determine the availability of information and to arrange for data acquisition. Most of the data were obtained by personal interviews during field trips after locating information sources by telephone. Some data were obtained by telephone or by having the contacts complete data sheets sent to them. A standard data form was prepared for use in the inventory. Data collected and included in the database are: location, date of occurrence, number of subsidence features at the reported site, size, topographic setting, geologic setting, and probable causative factors.

Data obtained in Phase I were compiled, and location data were displayed using computer plots of the study region. Potential areas for performance of the Phase II detailed reconnaissance study were identified on the basis of clustering of data points on the subsidence location plots which indicated areas having a relatively high frequency of subsidence.

Objectives of the Phase II investigations were to obtain detailed information on the distribution of old sinkholes and the recent activity reported in the inventory. These data were obtained to enable comparison with data from developed sites geologically analogous to an undeveloped study site at Oak Ridge. Detailed mapping of karst features has been performed at Oak Ridge (Ketelle and Huff, 1984). Two types of sites were desired for inclusion in Phase II; a site having rural/suburban development typical of the region in the vicinity of the DOE Oak Ridge Reservation, and a site developed for the purpose of solid waste disposal by land burial.

Four areas were identified for consideration in Phase II. Three areas had rural/suburban type development, and one area included an operating sanitary landfill. After field inspection of the four areas, one of the three rural/suburban areas was selected for Phase II study. The selected study area is underlain by bedrock of the Copper Ridge dolomite and Chepultepec dolomite as is the Oak Ridge study area (Ketelle and Huff, 1984). The rural/suburban site was located in Hamblen County, Tennessee approximately 55 miles (90 km) east-northeast of Oak Ridge.

Study Results

Phase I

The Phase I inventory resulted in obtaining data on 256 cases of sinkhole subsidence at 201 sites. Several sites had multiple subsidence features. Locations of the reported subsidence incidents are shown on Figure 1. The data obtained in this inventory probably account for only a fraction of the total amount of subsidence in the region because some sources at the municipal level, consultants, and private landowners were not identified.

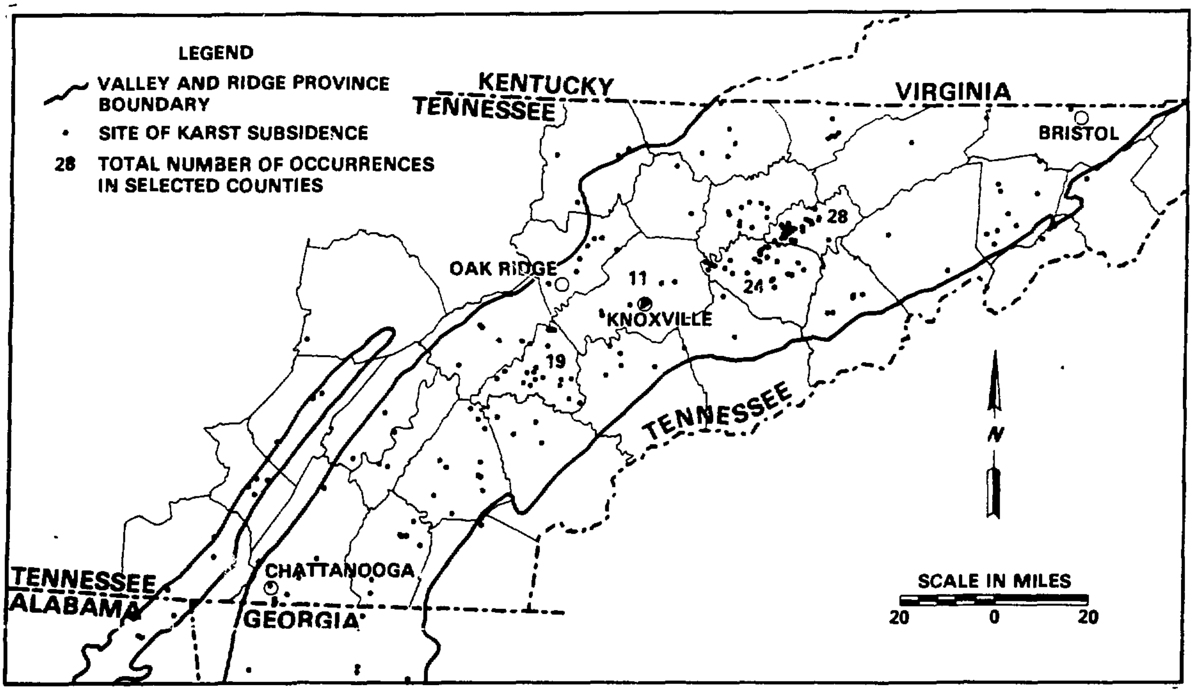

Figure 1. Location of karst subsidence sites identified in East Tennessee regional inventory.

The density of reported subsidence in east Tennessee is greatest in Loudon, Hamblen, and Jefferson Counties. Dates of reported sinkhole occurrence ranged from 1945 to 1986 with the largest number having occurred since 1980. The temporal distribution of occurrences is shown on Figure 2. The maximum surface dimensions of reported sinkholes ranged from 1 to 200 feet (0.3 - 60 m). A summary of the maximum surface dimension of reported sinkholes is shown on Figure 3. Approximately 60% of reported sinkholes were smaller than 20 feet in maximum surface dimension, 18% were larger than 20 feet, and 22% were of unknown size.

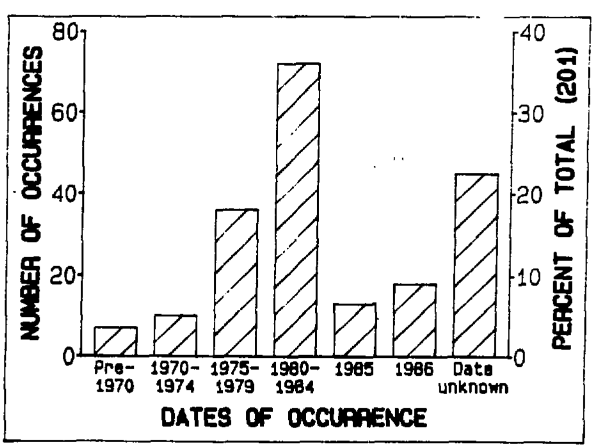

Figure 2. Temporal distribution for reported karst subsidence incidents.

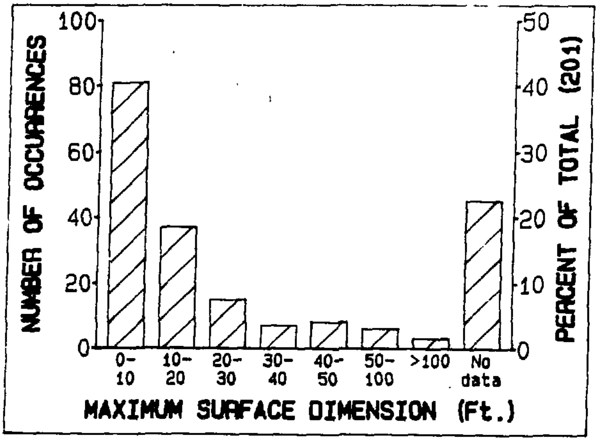

Figure 3. Maximum surface dimension size distribution for reported karst subsidence incidents.

Sinkholes were reported to have occurred in areas underlain by numerous geologic units. Distribution of the sinkholes among the major stratigraphic groups within the Valley and Ridge Province are shown on Figure 4. Within the study area karst activity is most prevalent in the Knox Group. The most common topographic setting for reported sinkholes was in valleys or flat areas (42%). About 22% of reported sinkholes occurred on hillslopes, about 7% on hilltops, and topographic setting data were unavailable for 29% of the sinkholes reported.

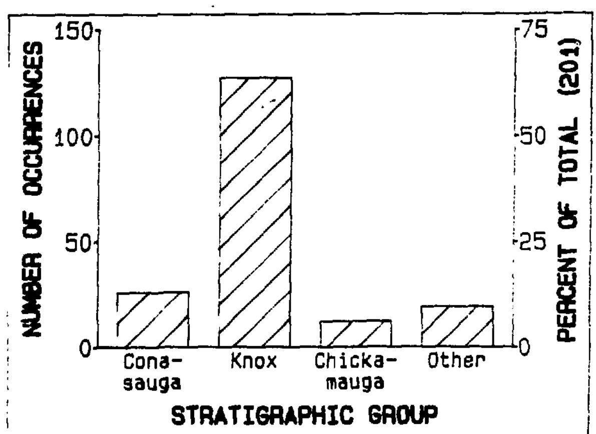

Figure 4. Distribution of reported subsidence incidents among major carbonate stratigraphic groups in East Tennessee.

The probable cause of about 57% of the reported subsidence incidents was construction activity, with inadequate surface water management being a commonly identified contributing factor leading to subsidence. In only about 1.5% of the reported incidents in East Tennessee was groundwater withdrawal suspected to be the causative factor.

Phase II

Phase II detailed reconnaissance was performed on a 5.5 square mile area in Hamblen County, Tennessee. Data obtained during the detailed reconnaissance included: location and approximate dimensions of all sinkholes, dolines, collapse features, and karst depressions; spring locations and bedrock orientation data were collected to supplement data published on the Morristown, Tennessee and Talbott, Tennessee geologic quadrangle maps (Finlayson et al., 1965; Oder and Milici, 1965). Basemaps used for the reconnaissance mapping were U.S. Geological Survey 7.5-minute quadrangles having a contour interval of 20 feet. The USGS maps showed 49 dry sinkholes and 10 sinkhole ponds within the area. Detailed reconnaissance mapping revealed the presence of 102 additional karst features within the mapped area. Approximately 70 (69%) of the features identified in the reconnaissance were old depressions, and the other 32 (31%) were features young enough for approximate dates of occurrence to be obtained from local residents. Bedrock dip in the area ranged from about 10° to 30°. The USGS map showed the location of 1 spring, and the reconnaissance mapping identified six additional springs in the study area.

The average areal density of karst features, including old and recent features, in the study area was approximately 1 per 22 acres. The highest areal density observed was in an area of about 2 acres which contained 13 recent karst features. This area was in a borrow pit where no regard was taken for surface water management. Many of these features occurred where piping eroded weathering rinds of bedrock pinnacles exposed by excavation. The average areal density of recent features in the study area was approximately 1 per 110 acres. Dates of the recent activity ranged from 1945 to 1986.

The area studied included bedrock of the Conasauga Group (Maynardville limestone), and Knox Group (Copper Ridge, Chepultepec, and Longview dolomites). Active subsidence was most abundant in the Longview dolomite, next most abundant in the Copper Ridge dolomite, and least abundant in the Maynardville limestone. Data on causative factors in Phase II were consistent with those of Phase I. The combination of soil disturbance by excavation or construction and allowing surface water to pond and infiltrate through disturbed soils was the most commonly suspected cause of subsidence.

Conclusions

This regional inventory of karst subsidence activity in East Tennessee confirmed that sinkhole activity is widespread in the Valley and Ridge Province. Karst activity has been documented in almost every carbonate geologic formation in the region and even in some non-carbonate lithologies which are underlain by carbonates at shallow depths. Most of the more than 250 subsidence incidents reported occurred since 1975. Outcrop belts of the Knox Group account for more than 65% of reported incidents. Approximately 60% of the reported recent sinkholes were twenty feet or less in their maximum surface dimension.

A detailed reconnaissance performed in one of the more active portions of the region located a total of 161 karst features, including old and recent features, in a 5.5 square mile area underlain by Knox Group dolomites. A common causative factor in subsidence was noted in both the regional inventory and in the detailed reconnaissance. The condition which was most commonly attributed as the cause was localized infiltration of surface water in soils disturbed by excavation or construction.

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