EFFECTS OF THE PALEOZOIC-CRETACEOUS UNCONFORMITY ON THE AQUIFERS OF NORTHEAST MISSISSIPPI

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Introduction

Purpose and Scope: Paleozoic sedimentary rocks ranging in age from Ordovician to Pennsylvanian are unconformably overlain by Upper Cretaceous sediments in northeast Mississippi (Figure 1). Because both the Paleozoic and Cretaceous stratigraphic sections contain the primary aquifers in the region, it is important to gain a better understanding of the geologic framework and the factors that controlled the occurrence and stratigraphy of the aquifers. Although the general structural configuration of the Paleozoic-Cretaceous unconformity in Mississippi has been known for many years (Mellen 1947), data is sparse and interpretations problematical in many areas, resulting generally in a poor understanding of one of the most important factors that influenced the stratigraphy of the Cretaceous section--the pre-existing topography upon which the sediments were deposited.

Even less understood than the structural configuration of the unconformity are the Paleozoic subcrop geology and the suitability of the Paleozoic rocks as aquifers. Although the Paleozoic rocks are significant aquifers in Alcorn and Tishomingo counties, providing an estimated five million gallons of water per day, data concerning their hydrogeologic characteristics is sparse.

As will be illustrated in this paper, the Paleozoic-Cretaceous unconformity significantly influenced the thickness and lithologic character of the lower part of the Upper Cretaceous stratigraphic section and the potential of the Paleozoic rocks as aquifers. The effects of the unconformity are seen on both regional and localized scales. This paper presents some preliminary observations and interpretations of the nature and significance of the unconformity in a portion of northeast Mississippi as part of an on-going effort by the Mississippi Office of Land and Water Resources to describe the hydrogeology of the region. The results of this study will eventually be utilized in the development of a regional ground-water flow model and in ground-water resource management. This paper augments and builds upon the work of many previous authors.

Methods: Geophysical well logs from water wells, oil and gas test holes, and other test holes, coupled with well cuttings and cores were used extensively in constructing various subsurface geologic maps and cross sections and in the interpretation of hydrogeological characteristics of the Paleozoic and Upper Cretaceous strata. Over 1,000 geophysical logs have been utilized, and cuttings and cores representing over 15,000 feet of borehole length have been examined to date. The greater availability of data in Alcorn and Tishomingo counties allows more detailed mapping of the unconformity and the Paleozoic subcrop geology in those areas. Field examinations of outcrops of Cretaceous and Paleozoic sections were also conducted to provide assistance in correlation of surface to subsurface data.

In the Fall of 1990, the Mississippi Office of Geology and the Office of Land and Water Resources drilled three stratigraphic test holes in Alcorn and Prentiss counties to obtain supplemental and more accurate geologic data on the Cretaceous and Paleozoic aquifers. Geophysical well logs and cores of Paleozoic rocks were obtained in two locations in Alcorn County. The cores were sampled for thin section examination.

Geologic Framework

Stratigraphy: Upper Cretaceous sediments consist primarily of poorly consolidated sands, gravels, and clays. With the exception of the Tuscaloosa interval, the Upper Cretaceous sediments were deposited in shallow marine environments in northeast Mississippi (Russell et al. 1983). The Tuscaloosa consists of gravels, sands, and kaolinitic clays deposited primarily in non-marine environments, predominantly by southward-flowing streams (Marcher and Stearns 1962; Russell 1987). Sediments that form important aquifers are found within the Tuscaloosa Group, the Eutaw Group (Eutaw and McShan formations, Merrill et al. 1988), and the Coffee and Ripley formations of the Selma Group (Boswell 1963). Cretaceous units that are generally considered aquitards or aquicludes are the Mooreville and Demopolis "chalks", the lower part of the Ripley, and the Owl Creek/Prairie Bluff formations.

Beneath the unconformity, limestones, cherty limestones, cherts, and calcareous shales predominate the Ordovician, Silurian, Devonian, and Lower Mississippian (Iowa) stratigraphic sections, whereas sandstones and shales with some limestone intervals constitute the Upper Mississippian (Chester) section (Mellen 1947; Thomas 1972 and 1988; Cleaves and Broussard 1980; Alberstadt and Repetski 1989). Pennsylvanian rocks are predominantly sandstones, shales, conglomerates, and coal beds (Mellen 1947; Cleaves and Broussard 1980; Beard and Meylan 1987).

In Mississippi, Paleozoic outcrops are limited to small areas of Tishomingo County, primarily along the shores of Pickwick Lake in the northeastern part of the county. There, the Lower Mississippian Fort Payne and Tuscumbia formations are exposed along with minor outcrops of the Devonian Chattanooga Shale and Ross Formation (Merrill et al. 1988). Rocks of the Mississippian Tuscumbia, Pride Mountain, and Hartselle formations crop out in limited areas of southern Tishomingo County. No Paleozoic rocks younger than the Hartselle Sandstone are known to crop out in Mississippi. Chert and cherty limestones of the Fort Payne and Tuscumbia formations are the fresh-water bearing units utilized to date in northern Tishomingo and eastern Alcorn counties while Devonian chert is thought to constitute the main aquifer at Corinth (Boswell 1963).

Critical to an understanding of the nature and aquifer potential of the Paleozoic section is an accurate understanding of the subcrop geology. The Paleozoic subcrop map shown in Figure 2 generally supports but updates the subcrop interpretations of Mellen (1947), Marcher and Stearns (1962), and Boland and Minihan (1971).

Structure: The Paleozoic-Cretaceous unconformity generally dips to the west at a rate of approximately 25-30 feet per mile (Figure 3). This structural configuration is primarily the result of subsidence to the west during the formation of the Mississippi Embayment in Late Cretaceous and Tertiary time, following deposition of the lower part of the Upper Cretaceous section (Mellen 1958).

Paleozoic strata generally dip to the south-southwest at rates of approximately 40-60 feet per mile. The subcrop map (Figure 2) supports the interpretation of Wilson (1949), Grohskopf (1955), and Stearns and Marcher (1962) that northeastern Mississippi was once the southeastern flank of a large structural high, the Pascola Arch, with a crest in western Tennessee and southeastern Missouri, that was eroded and subsided into the present Mississippi Embayment. The occurrence of progressively older Paleozoic strata from south-southeast to north-northwest across northeast Mississippi provides evidence of the existence of this foundered ancient land area.

Influence of the Unconformity Upon Sedimentation and Hydrogeology

Effects Upon Eutaw and Tuscaloosa Aquifers: Evidence that the northwest part of the study area remained a structurally positive area during the time of deposition of the lower part of the Upper Cretaceous section is shown by the regional isopach (thickness) map of the Tuscaloosa Group (Figure 4). The Tuscaloosa section thins and eventually pinches out to the northwest onto the southeast flank of the paleohigh. In addition, the paleohigh also influenced the depositional facies of the Tuscaloosa Group. The Tuscaloosa in the area immediately east and southeast of the paleohigh consists primarily of poorly sorted, non-marine chert gravels, whereas farther to the east and southeast, well sorted, marine sands and gravels were deposited farther down the paleoslope (Marcher and Stearns 1962).

Thinning onto the paleohigh is also evident in the overlying Eutaw Group (Figure 5). Eutaw sediments extend farther to the northwest than the Tuscaloosa, indicating the overall onlapping nature of the lower part of the Upper Cretaceous section. The Eutaw Group also changes character as it extends onto the paleohigh. The McShan Formation pinches out to the northwest (Monroe et al. 1946; Cook 1986; Merrill et al. 1988), and the Eutaw Formation, which also thins, becomes more argillaceous with correspondingly lower hydraulic conductivity to the northwest.

It should be noted that not all of the thinning of these units is due to non-deposition -- evidence of erosion occurs at the top of the Tuscaloosa Group and at the top of the McShan Formation (Monroe et al. 1946; Russell et al. 1983). In southern Tennessee the Eutaw Formation is disconformably overlain by the Coffee Sand (Russell 1975).

In addition to the regional effects, there is also significant evidence of more localized paleotopography that likely developed during the long exposure of the Paleozoic section prior to renewed deposition in the Late Cretaceous. Although some of the local topography of the unconformity could be the result of differential subsidence or reactivation of old fault zones, there is little evidence that major faults occur in the Upper Cretaceous or Tertiary sections. The faults known to exist in the sediments overlying the Paleozoics are of much smaller magnitude than those mapped in the Paleozoic section (Boland and Minihan 1971; Bat 1987). Merrill et al. (1988) also noted the absence of significant faults in the Upper Cretaceous of Tishomingo County. Indication that erosional topography developed on the exposed Paleozoics is demonstrated by infilling of paleotopographic lows by Cretaceous sediments. Merrill et al. (1988) illustrated the infilling of a large paleovalley that extends from western Tishomingo County into Prentiss County by Tuscaloosa clastic sediments. Figure 6 is a cross section illustrating the northern part of this feature in southeastern Alcorn and northeastern Prentiss counties. Similar infilling, but of a smaller magnitude, has been noted by the authors in the Corinth area. Paleokarst topography and local relief on the unconformity of at least 30 meters has been described by Sigleo and Reinhardt (1988) in southwestern Kentucky, western Tennessee, and northwestern Alabama.

Effects upon the Paleozoic Aquifer: The unconformity influenced the capacity of the Paleozoic rocks to serve as aquifers by controlling or influencing the following factors:

1. The Paleozoic subcrop geology indicates which rock units are available beneath the unconformity to act as potential aquifers. Cores recovered during the drilling of two stratigraphic test holes in Alcorn County revealed significant differences in Paleozoic aquifer petrophysical characteristics between the two locations, differences due primarily to the cores being from different geologic formations and depositional facies. There are numerous examples in the geologic literature of the control of depositional facies on porosity and permeability (e.g., Saller et al. 1991).

2. The long period of exposure and erosion of the Paleozoic rocks likely modified the existing porosity and permeability by chemical, mechanical, and biotic weathering. Unconformities are noteworthy as environments that commonly create or enhance porosity and permeability (Levorsen 1967). The effects of weathering can extend to depths of many hundreds of feet (Ollier 1975), especially in a warm, humid climate that likely existed in northeastern Mississippi during exposure of the Paleozoics (Sigleo and Reinhardt 1988). Dissolution of both cements and framework grains can occur at and near unconformities (Shanmugam and Higgins 1988). However, the relationships of the effects of weathering to the complex structural and diagenetic history of the Paleozoic rocks of northeast Mississippi are not well understood.

3. Hydraulic interconnection of the Upper Cretaceous aquifers with the Paleozoic aquifers occurs to varying degrees at the unconformtiy. As illustrated in Figure 6, thick Cretaceous aquifers can occur both above and laterally adjacent to porous and permeable Paleozoic rocks, indicating likely hydraulic interconnection. However, the variable presence and character of paleosols (commonly kaolinitic clays) beneath the Upper Cretaceous sediments (Mellen 1937; Sigleo and Reinhardt 1988) may impede hydraulic interconnection locally. The local presence of clay beds at the unconformity has been cited as an important factor in water quality considerations at Corinth (Swann 1989). Water from the Paleozoic aquifer commonly contains less dissolved iron but may be harder.

Summary and Recommendations

The hydrogeologic characteristics of the sediments and rocks in northeast Mississippi are largely the products of the geologic history of the region. Because the Cretaceous aquifers are thin in extreme northeastern Mississippi, and the Tertiary aquifers are not present, it is necessary to gain a better understanding of the complex Paleozoic geology and the relationships of the Paleozoics to the Upper Cretaceous sediments.

A significant factor in the paucity of data concerning the unconformity is that it essentially represents an interface between the realms of the hydrogeologist and the petroleum geologist. Most of the petroleum exploration wells, drilled deep into the Paleozoic section, are not logged above surface casing which is usually set in the uppermost part of the Paleozoics. In addition, even in those instances in which geophysical logs are run across the unconformity into the Cretaceous section, suites of logs are rare.

Geophysical logging suites, considered a necessity in petroleum reservoir exploration and engineering, are rare in the water well industry. Closer cooperation of hydrologists with the petroleum industry in data collection would be beneficial to workers in both realms. A synergistic approach of utilizing a variety of logging tools, each designed to measure different petrophysical properties (Keys 1989), coupled with geologic data obtained from well cuttings and cores should be applied more vigorously in hydrogeologic studies, especially in areas such as northeast Mississippi.

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