Control and distribution of porosity in the Red River C laminated member at the Brush Lake Field
by James Roy Stimson

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Earth Sciences
Montana State University

Abstract:
The Red River "C" cycle at the Brush Lake field consists of three distinct informal members; 1) the anhydrite member, 2) the laminated member, and 3) the burrowed member, in descending order.

This cycle can be interpreted as a tidal flat deposit with the above members representing the supratidal, intertidal, and subtidal environments, respectively. The laminated member has been thoroughly dolomitized at Brush Lake and porosity values within the dolomites change rapidly. Evidence from Brush Lake reveals that the porosity distribution is primarily the result of diagenetic controls rather than structural or depositional controls. Textural evidence from the laminated member indicates that porosity has been reduced in some parts of the laminated member by 1) early precipitation of calcite cements, 2) overdolomitization, 3) early precipitation of gypsum, 4) late precipitation of replacive anhydrite, and 5) pressure solution along low amplitude stylolites.

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APPROVAL

of a thesis submitted by

James Roy Stimson

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Signature James Roy Stinson

Date 05/08/85

This thesis is dedicated to the memory of Dr. Don Smith, whose signature of approval would have given me great satisfaction.

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ABSTRACT

The Red River "C" cycle at the Brush Lake field consists of three distinct informal members; 1) the anhydrite member, 2) the laminated member, and 3) the burrowed member, in descending order. This cycle can be interpreted as a tidal flat deposit with the above members representing the supratidal, intertidal, and subtidal environments, respectively. The laminated member has been thoroughly dolomitized at Brush Lake and porosity values within the dolomites change rapidly. Evidence from Brush Lake reveals that the porosity distribution is primarily the result of diagenetic controls rather than structural or depositional controls. Textural evidence from the laminated member indicates that porosity has been reduced in some parts of the laminated member by 1) early precipitation of calcite cements, 2) overdolomitization, 3) early precipitation of gypsum, 4) late precipitation of replacive anhydrite, and 5) pressure solution along low amplitude stylolites.

INTRODUCTION

Statement of Problem

Drilling activity in the Williston Basin of eastern Montana has in the last 10 to 15 years established the Red River Formation and particularly its "C" laminated member as an important reservoir for hydrocarbons. The "C" laminated member is thoroughly dolomitized in many parts of the basin and produces hydrocarbons where dolomitization has resulted in a substantial increase in the volume of intercrystalline porosity. Determining where porosity is sufficient for hydrocarbon production remains a major difficulty because even within thoroughly dolomitized portions of this member porosity values change rapidly. For example, it is not uncommon for one well penetrating this member to encounter dolomite with economically significant porosity (greater than or equal to 6 percent) while another well, less than a mile away, encounters dolomite with very little porosity (much less than 6 percent) (Plate 1). This is an interesting and important phenomenon because theoretically, complete dolomitization of limestone should result in an increase of porosity (Murray, 1960; Weyl, 1960). The fact that some parts of the "C" laminated member lack significant porosity despite being thoroughly dolomitized suggests other factors, in addition to dolomitization, contributed to the observed porosity distribution. The purpose of this thesis is to identify what other diagenetic processes affected the

"C" laminated member and to determine how these processes affected the distribution of economically significant porosity.

Stratigraphy

The term Red River Formation is applied to the Middle and Upper Ordovician carbonates in the subsurface of the Williston Basin (Fig. 1). The outcrop equivalent of this formation is the Bighorn Dolomite. The Red River Formation was originally described by Dowling (1900) and was defined as the carbonate sequence lying below the Ordovician Stony Mountain Shale and above the Ordovician Winnipeg Formation (Fig. 1). Numerous workers have studied and subdivided this formation; Dowling (1900), Foerste (1928), Ballie (1952), Porter and Fuller (1959), Andrichuk (1959), Sinclair (1959), Fuller (1961), Ballard (1963) and Friestad (1969). The Red River is most often subdivided into two parts; an upper unit composed of several carbonate/evaporite cycles and a lower unit comprised of massive dolomitic limestone (Porter and Fuller, 1959; Sinclair, 1959; Fuller, 1961). The boundary separating the upper and lower parts is placed at the base of the lowest anhydrite bed (the "C" anhydrite in Fig. 2) (Fuller, 1961). Another subdivision employed mainly by workers in the hydrocarbon industry divides the formation on the basis of the carbonate/evaporite cycles and this subdivision is employed in this thesis. According to this subdivision there are three general cycles labelled A, B, and C in descending order (Fig. 2). In the basin interior, each of these cycles is made up of three informal members; an upper anhydrite member, a middle laminated dolomite mudstone member, and

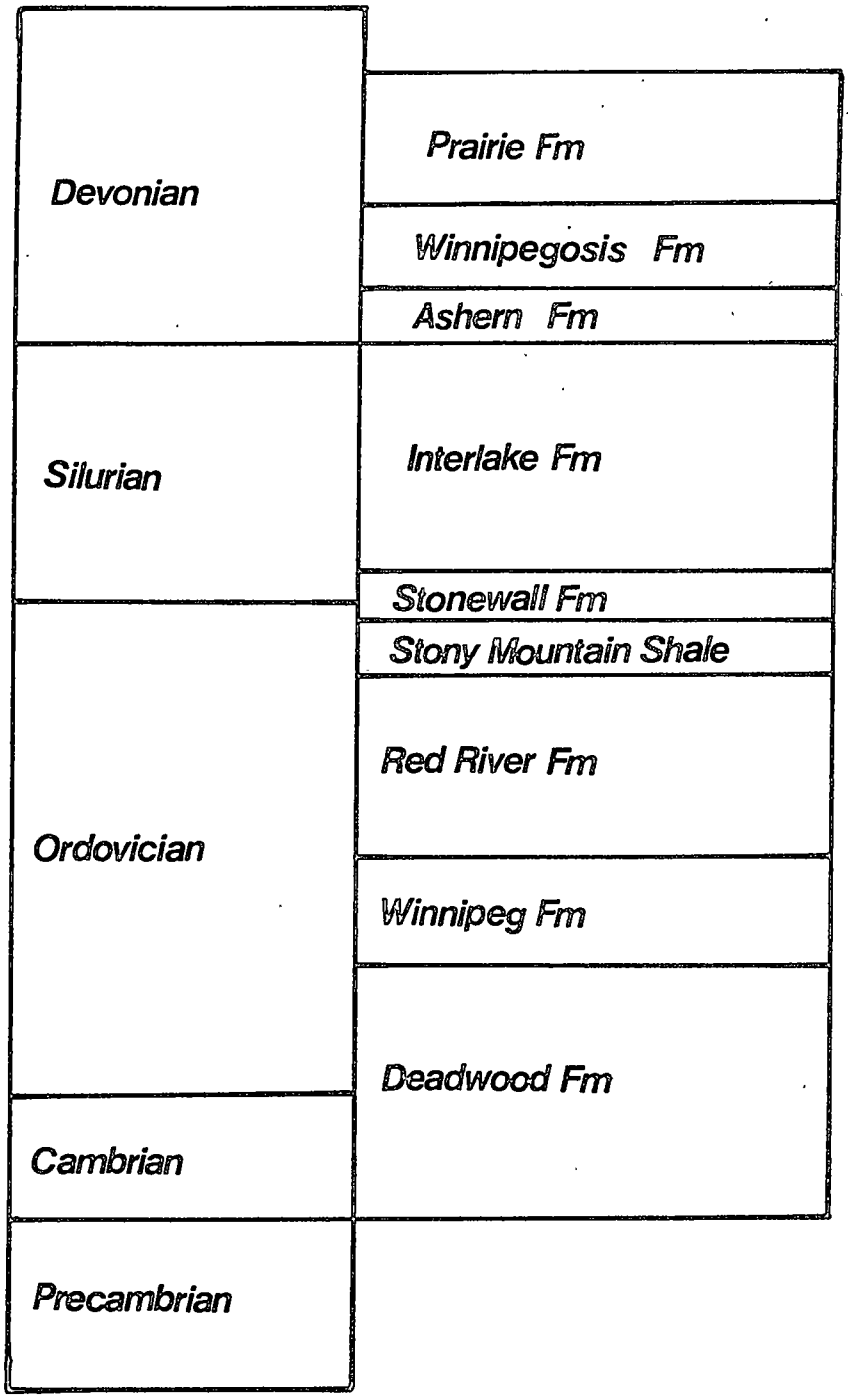

Figure 1. General stratigraphic column for the Williston Basin.

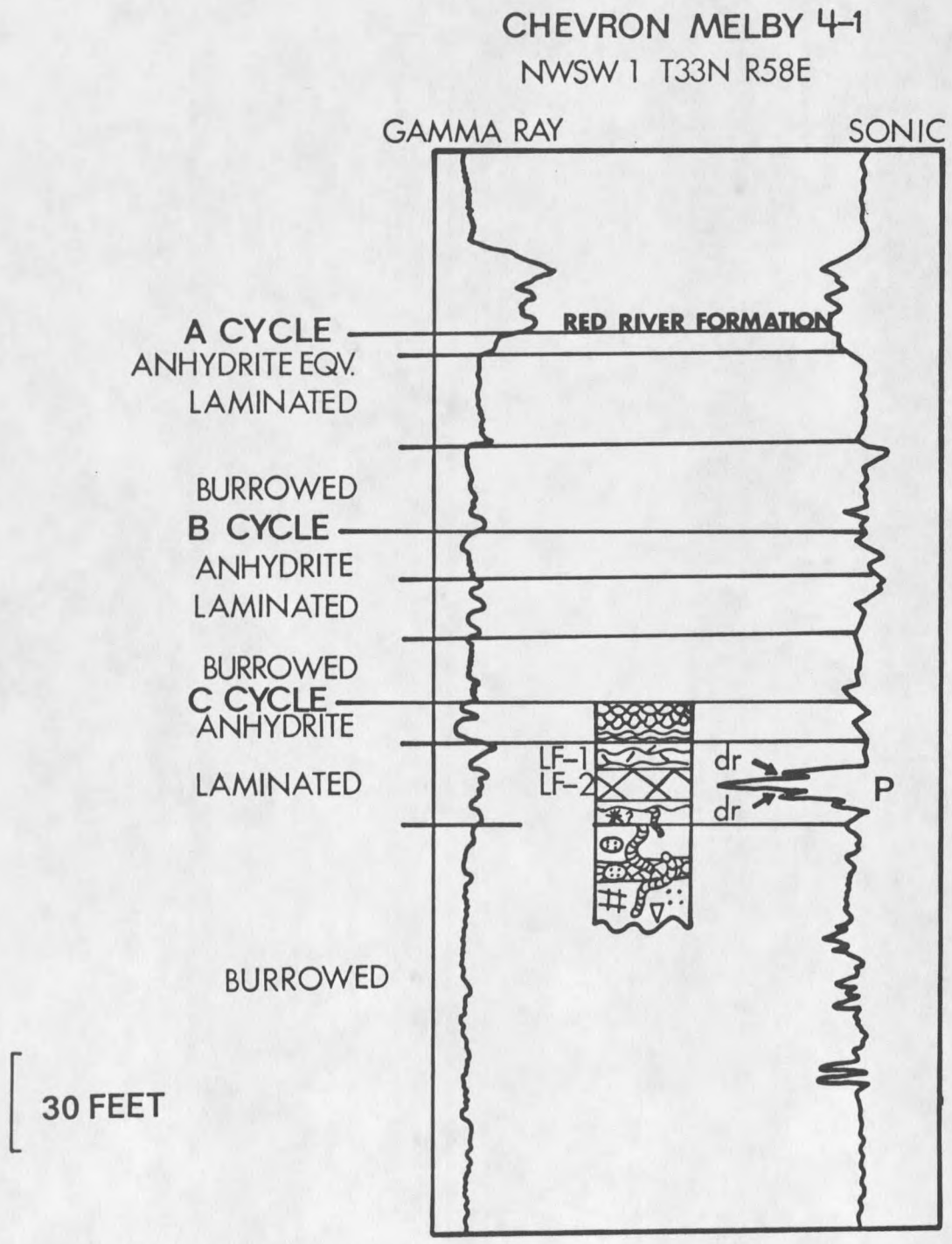

Figure 2. General log characteristics and terminology for the Red River Formation. P = porosity zone and dr = dolomitization resistive beds.

a lower bioturbated mudstone to wackestone member (Fig. 2). In this study, the three members of each cycle are referred to as 1) the anhydrite member, 2) the laminated member, add 3) the burrowed member. An "A", "B", or "C" will preceed these member terms to specify the Red River cycle under discussion. This study focuses on the "C" cycle and in particular the "C" laminated member.

To conduct a detailed study of the "C" cycle lithology and porosity distribution requires numerous core samples and mechanical logs. A search was made to locate a field where several wells had been cored. As a result, the Brush Lake field was chosen as the study area.

Study Area

The Brush Lake field located in Sheridan County, Montana (Fig. 3) is well suited for a detailed study of the Red River "C" cycle and to accomplish the thesis objectives. One reason for this is that the "C" laminated member is thoroughly dolomitized throughout the field and porosity values change rapidly over short distances. Another very important reason for choosing this study area is the fact that eight of the ten wells comprising the field have core samples of most, if not all of the "C" cycle. These extensive core samples made it possible to conduct a detailed examination of the entire "C" cycle. From this examination, the depositional environment, diagenetic history, and stratigraphic relations of the various lithologic units present in the "C" zone have been determined. Also, the textural and compositional characteristics of the "porous" and "nonporous" dolomites have been examined and compared. Therefore, the thorough dolomitization, the rapid changes in porosity in the laminated member, and the availability of extensive core samples make the Brush Lake field an ideal study area for this research project.

Brush Lake Structure and Structural Development

Figure 4 shows the present-day structure at the Brush Lake field using the "C" anhydrite base as the datum. From this map the Brush

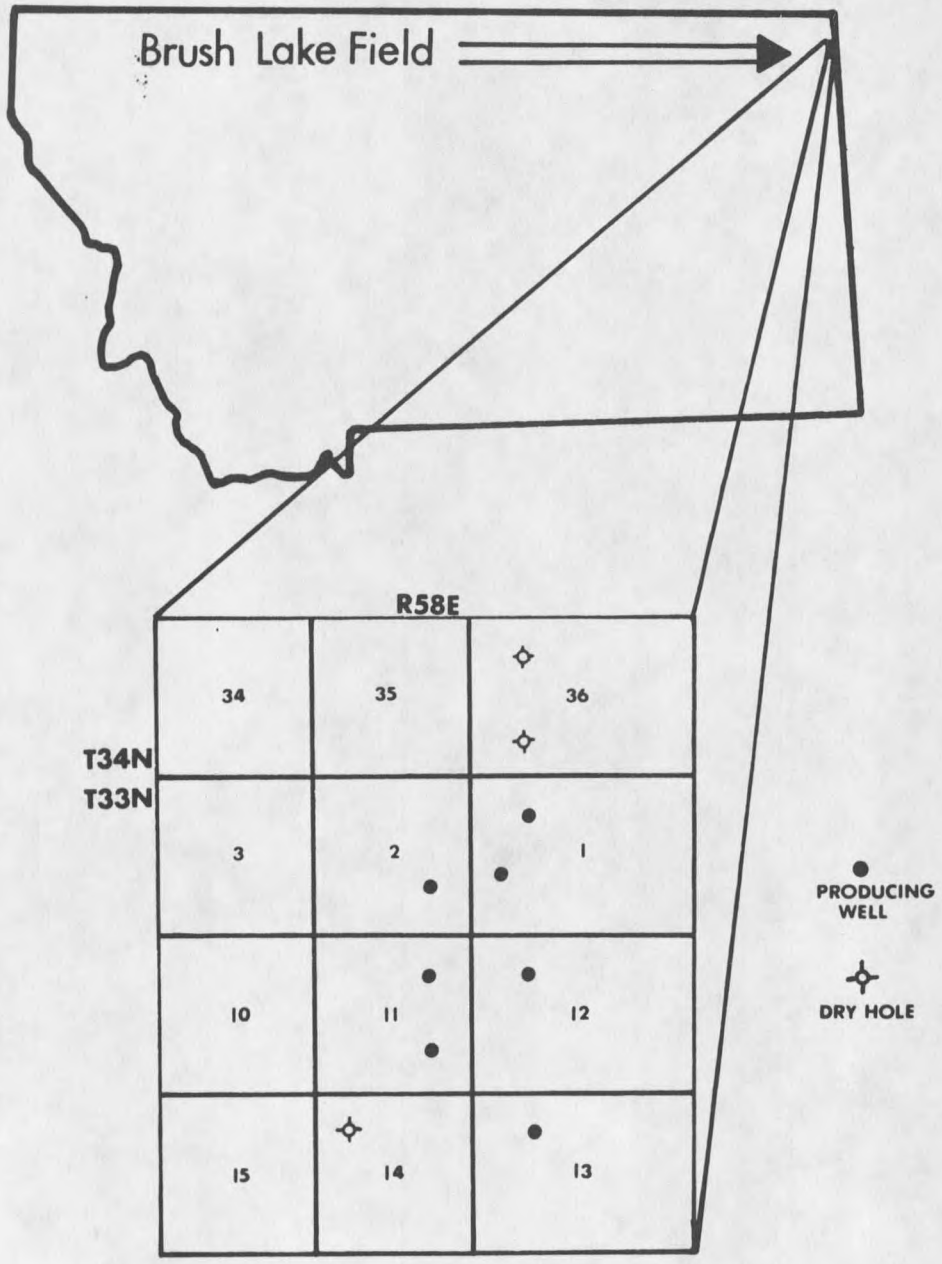

Figure 3. Location of study area and well locations for the Brush Lake Field.

Lake structure is observed to be about 4 miles in length and 2 miles wide. The structural axis trends roughly north-south. In addition, the Brush Lake structure can be seen to consist of two prominent "highs," one to the north and one in the south. The structural closure is approximately 100 feet on the northern high and about 40 feet on the southern part of the structure.

Although the Brush Lake structure has significant closure at present, the isopach maps reveal this was not always the case (Figs. 5 through 7). Figure 5 is an isopach of the "C" laminated member which shows that significant variations in thickness are lacking. The absence of substantial thickness variations within the laminated member indicates that during deposition of this member the Brush Lake structure was a subtle feature with total relief or closure probably not exceeding 4 to 6 feet.

Figures 6 and 7 show somewhat greater thickness variations than Figure 5 and indicate the structure had developed 20 feet of relief by the end of the Red River deposition and about 40 feet of relief by the end of Silurian time. The isopach maps are important because they clearly show that the Brush Lake structure did not become a prominent feature until sometime after Red River time. This means paleostructure could not have influenced penecontemporaneous dolomitization. Consequently, paleostructure did not control the porosity distribution within the "C" laminated member at the Brush Lake field.

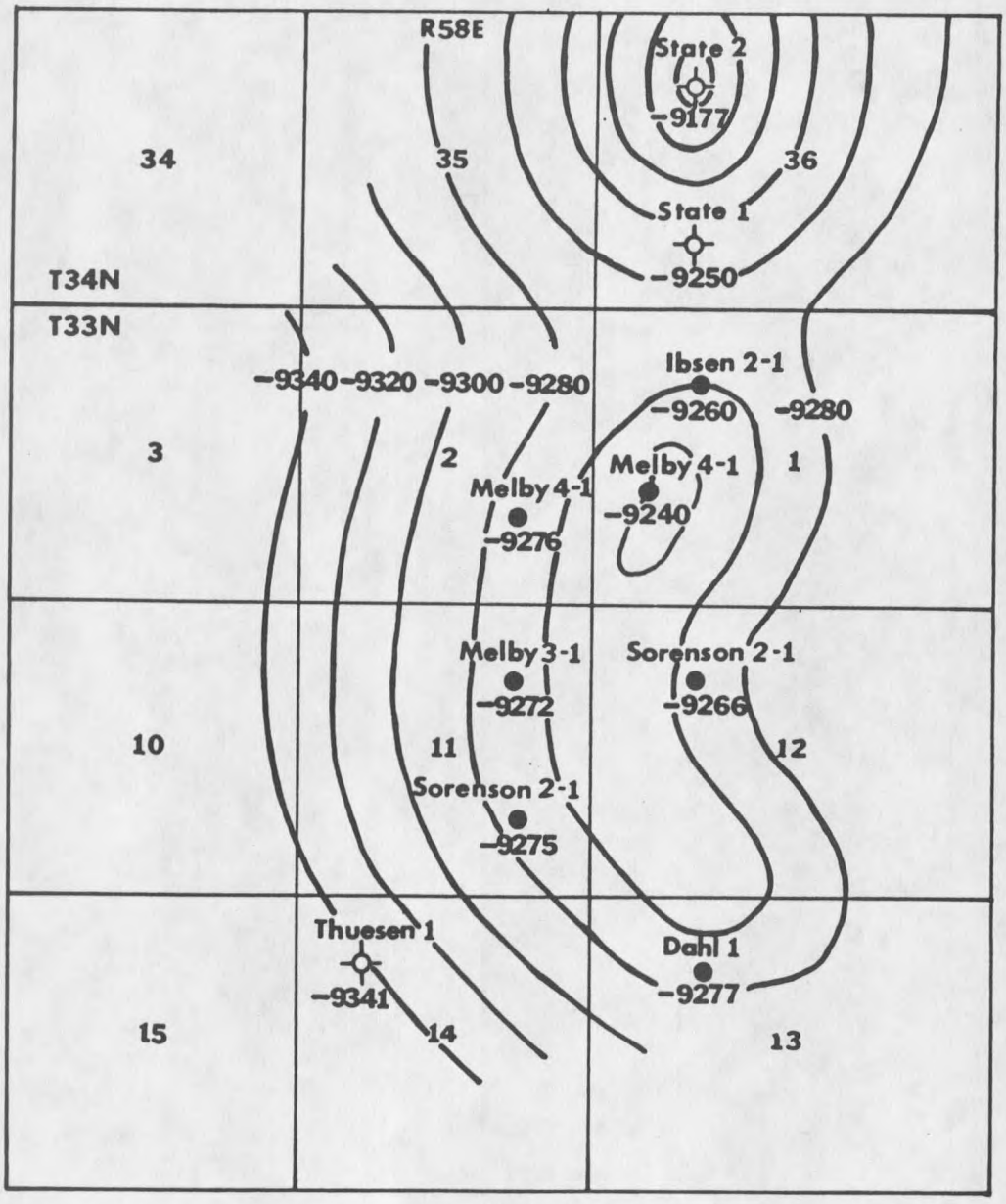

Figure 4. Structure map on the "C" anhydrite base. Contour interval = 20 feet.

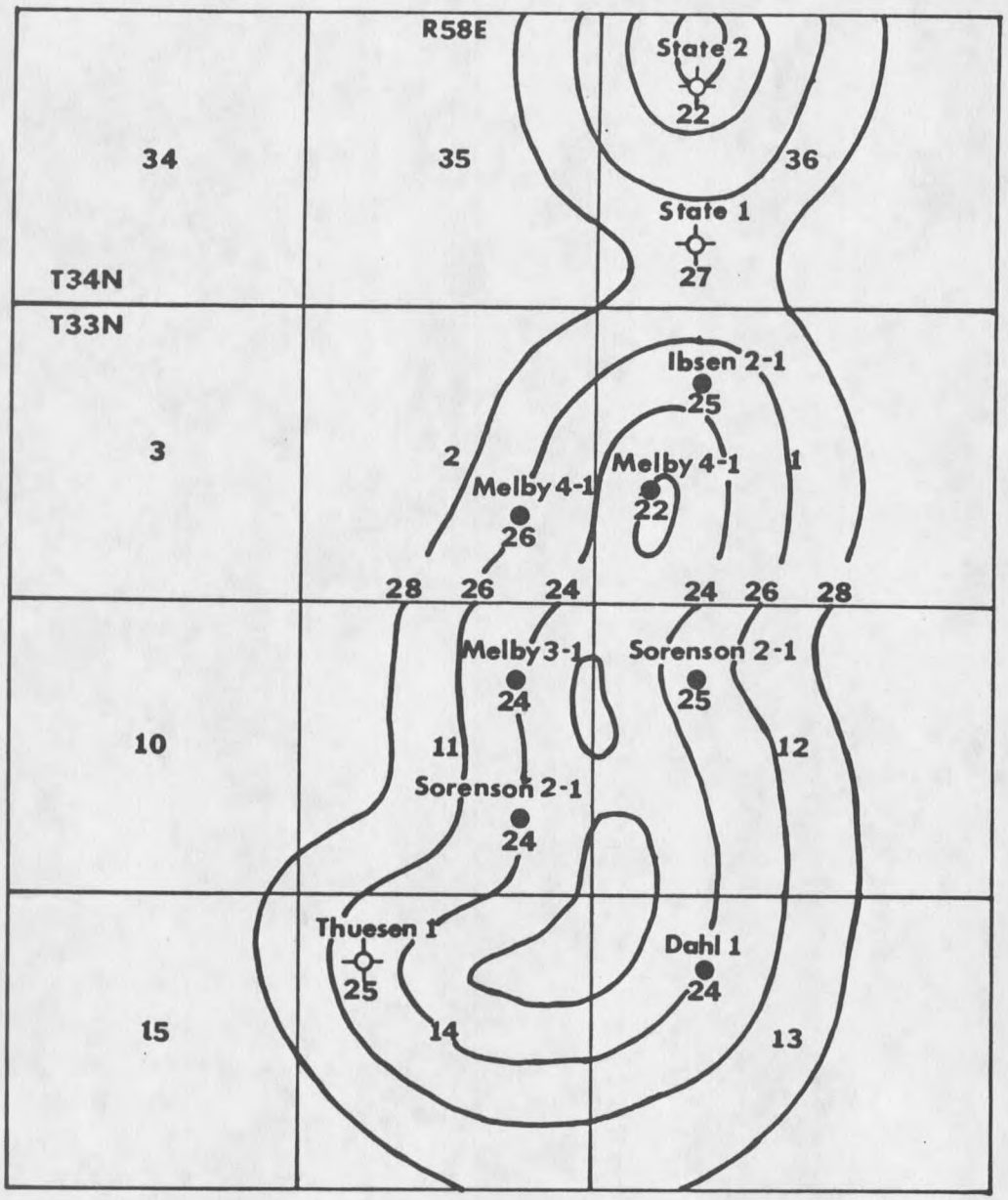

Figure 5. Isopach map of the "C" laminated member. Contour interval = 2 feet.

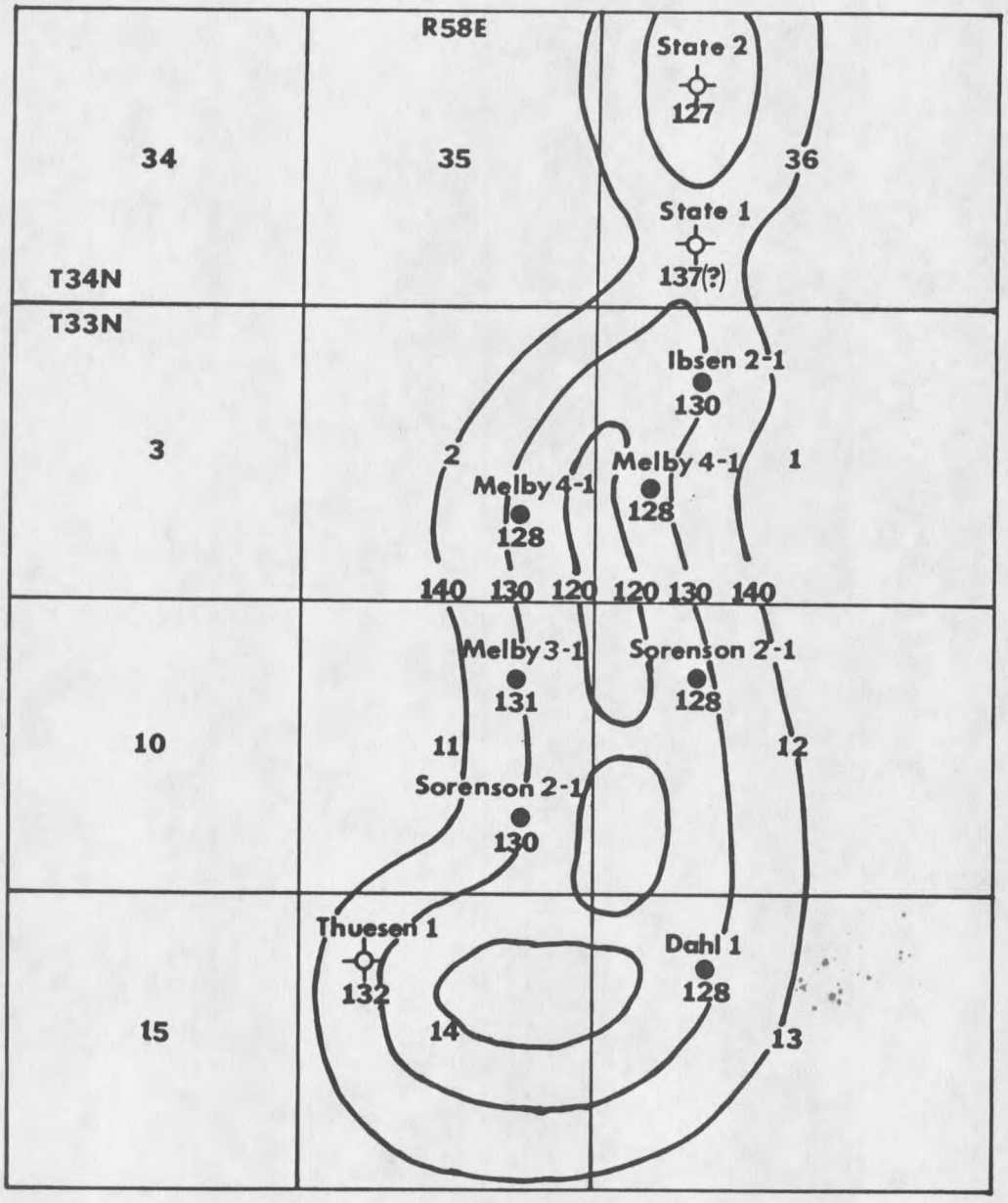

Figure 6. Isopach map of the Red River to "C" anhydrite base interval. Contour interval = 10 feet.