CHAPTER 2. GEOLOGIC SETTING

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Regional Geology

The Hugoton field lies on the west side of the Hugoton embayment of the Anadarko basin and is bounded to the northwest by the Las Animas arch and to the northeast by the Central Kansas uplift. The Anadarko basin is an asymmetric foreland basin associated with the Early Pennsylvanian Ouachita-Marathon orogeny caused by suturing of the Laurasian and Gondwanan plates when the super-continent Pangea formed (Kluth, 1986; Figure 2.1). The Hugoton embayment and the rest of the Kansas shelf formed the shallow and broad zone of flexural subsidence cratonward (Dickinson, 1974; DeCelles and Giles, 1996) of the deeper parts of the foreland basin (Figures 2.2 and 2.3). Subsidence in the Anadarko basin was most rapid immediately after it was initiated during Pennsylvanian-Morrowan, with subsidence rates decreasing through the Permian. The basin was nearly filled by the end of the Wolfcampian when the Anadarko basin was covered by shelf carbonates (Kluth and Coney, 1981; Rascoe and Adler, 1983; Kluth, 1986; Perry, 1989).

Wolfcampian marine-carbonate reservoirs thin towards the updip margin and many pinch out at, or just west of, the margin of the Hugoton and Panoma fields, particularly in the Council Grove Group. Red continental rocks, primarily very fine to coarse siltstones, are thickest at the western field margin and thin basinward across the shelf (Figure 2.4). These redbeds have been thought by many to be the lateral seal that, when accompanied by a Leonardian-age evaporite top seal, created a giant stratigraphic trap (Garlough and Taylor, 1941; Mason, 1968; Pippin, 1970; Parham and Campbell, 1993). However, laterally continuous marine- and continental sandstone with relatively high porosity and permeability are common at the updip margin in the northwest part of the field. These siliclastic rocks are gas productive inside the field boundaries, but despite being in a higher structural position and without evidence of physical barrier, water saturated outside the field (Dubois and Goldstein, 2005). These conditions argue against the red continental siliciclastic rocks being a lateral seal and suggest that mechanisms other than lithofacies change alone are responsible for trapping. Determining the trapping mechanisms and the sloped free water level (and gas-water contact recognized in the field) was not an objective in this study. However, theories put forth by earlier workers are discussed in Chapter 7.

Present-day structure of Wolfcampian rocks was strongly influenced by a Laramide eastward tilt (Figure 2.5), whereas the Wolfcampian isopach (Figure 2.6) better reflects the shelf geometry at the time of deposition. From the west field margin, the Wolfcampian strata thicken basinward at a rate of approximately 1.3 ft/mi (0.24 m/km) to a location on the shelf where the rate of thickening increases by a factor of 10. The axis of thickening is coincident with an area of present-day steep dip and may mark a shelf margin or the axis of a steepened slope. It is also nearly coincident with the edge of a Virgilian starved basin and transition from marine carbonate to marine shale (Rascoe, 1968; Rascoe and Adler, 1983). Dubois and Goldstein (2005) estimated the maximum relief across the Kansas portion of the shelf during Council Grove deposition to have been 100 ft (30 m) with a slope of approximately 1 ft/mi (0.2 m/km). Notable is the absence of dark, fissile shale on the Hugoton shelf, a common deep-water lithofacies in the Wolfcampian in outcrop in eastern Kansas and northeast Oklahoma (Boardman and Nestell, 2000; Mazzullo et al., 1995), suggesting that maximum water depths on the Hugoton shelf were less than those at the present day outcrop 300 mi (480 km) to the east. The closest equivalent to the typical deep water lithofacies in Hugoton core are dark marine siltstones found near the base of the marine carbonate intervals in four cycles, the Grenola (C_LM), Funston (A1_LM), Wreford, and Fort Riley. For this paper we will refer to the extremely gently sloping portion of the study area as shelf and the area of steeper dip and stratigraphic thickening as the shelf margin.

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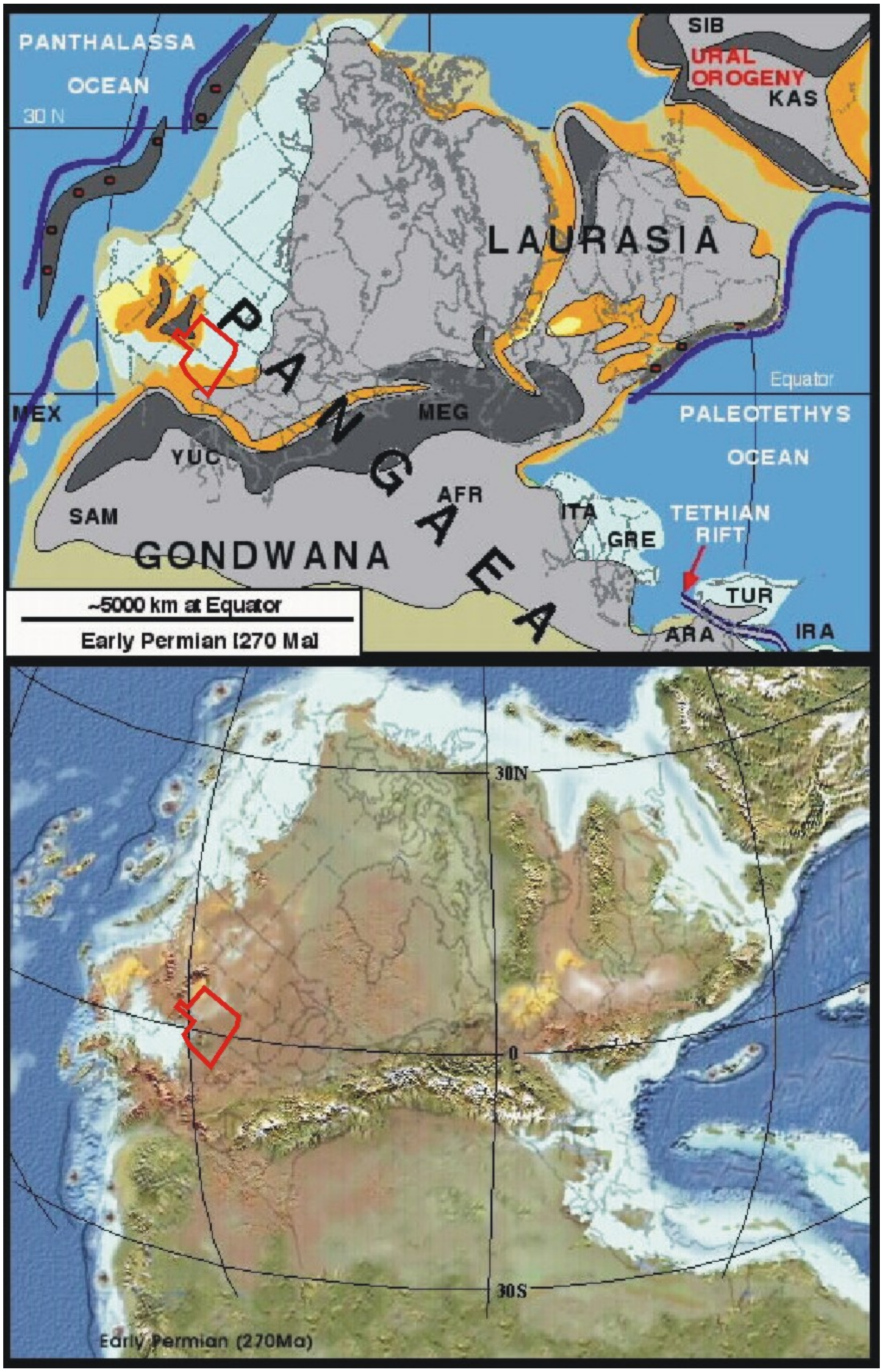

Figure 2.1. Early Permian paleogeography, 270Ma (after Blakey, data largely from Scotese, 1998). Kansas and Oklahoma are outlined in red.

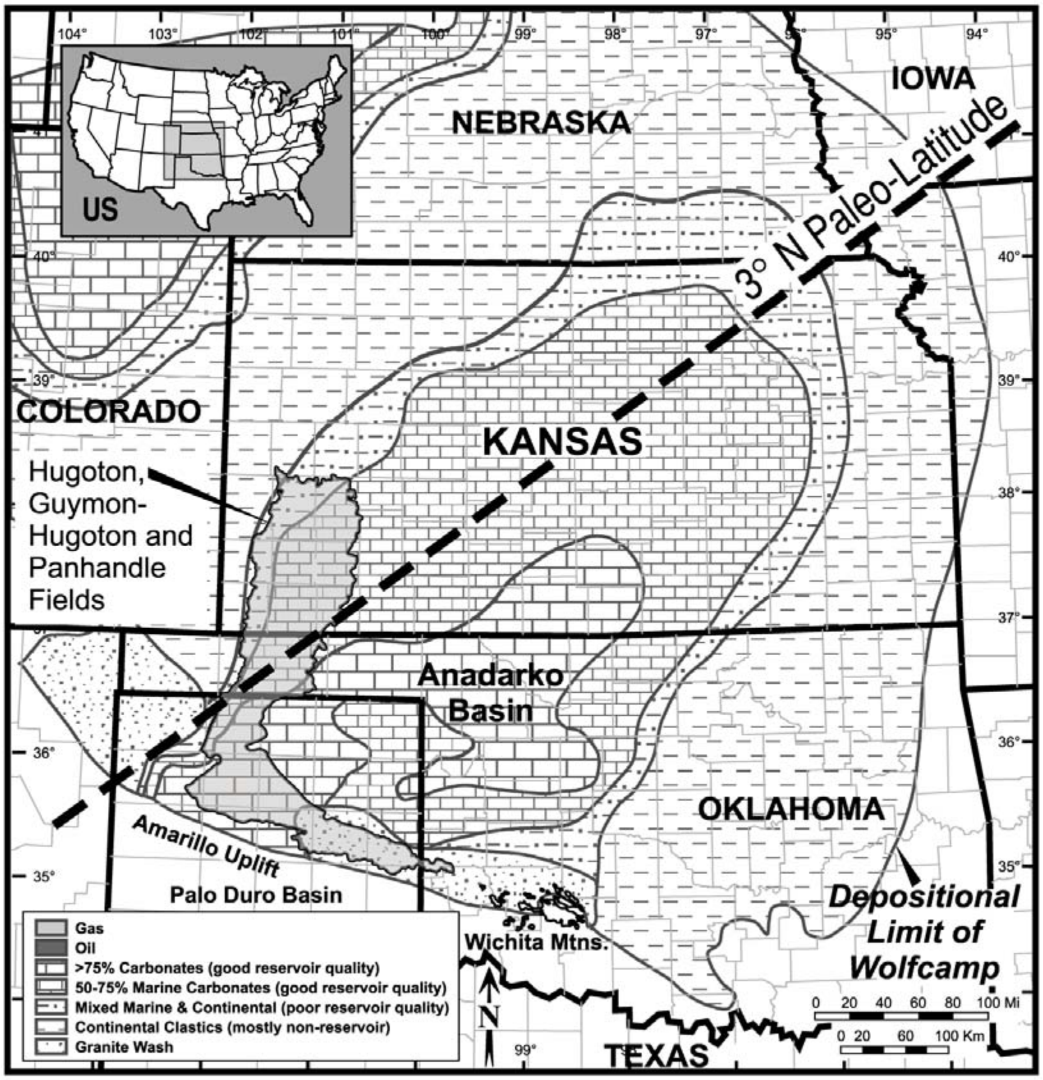

Figure 2.2. Distribution of major lithofacies in the midcontinent during the late Wolfcampian (after Rascoe, 1968; Rascoe and Adler, 1983; Sorenson, 2005. Approximate paleo-latitude was 3 degrees north (Scotese, 2004).

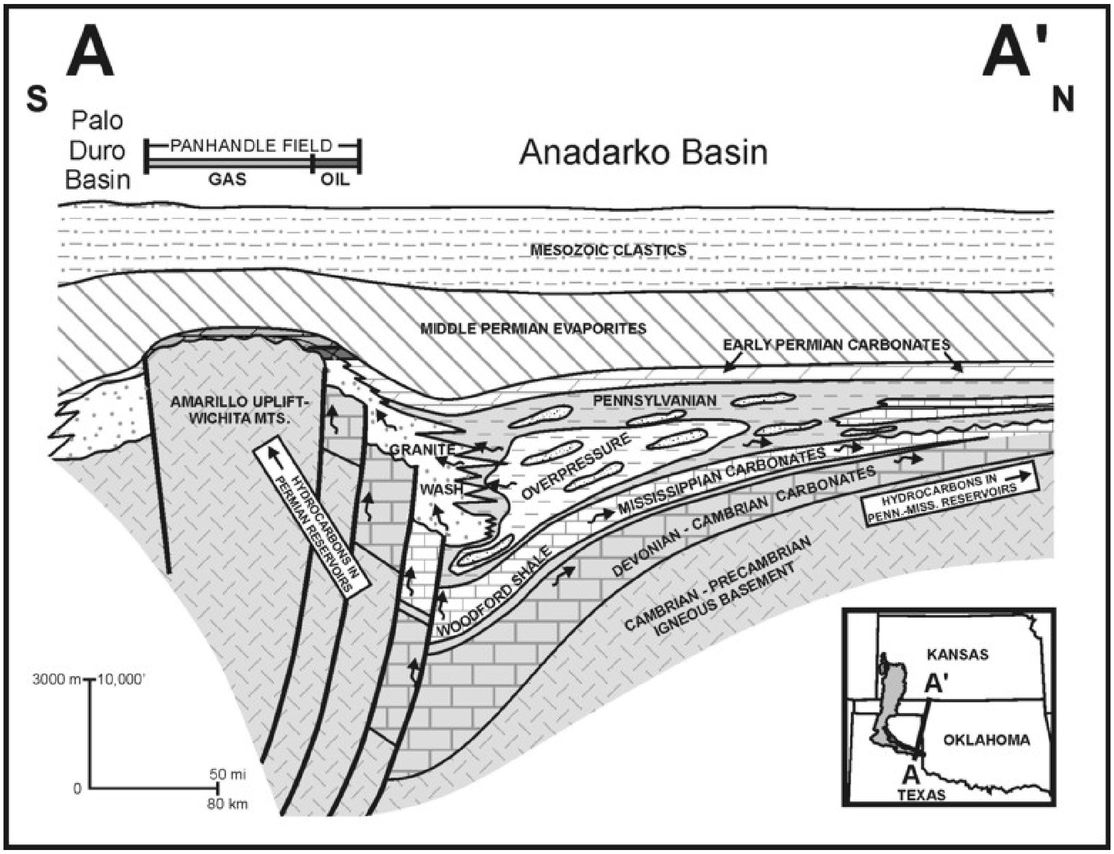

Figure 2.3. South-north cross section AA' through Anadarko basin (after Pippin, 1970; Dutton and Garret, 1989; Johnson, 1989; and Sorenson, 2005). Arrows depict Sorenson's (2005) postulated hydrocarbon-migration pathways. The broad Kansas shelf extends to the right (north) on the flat side of the asymmetrical basin.

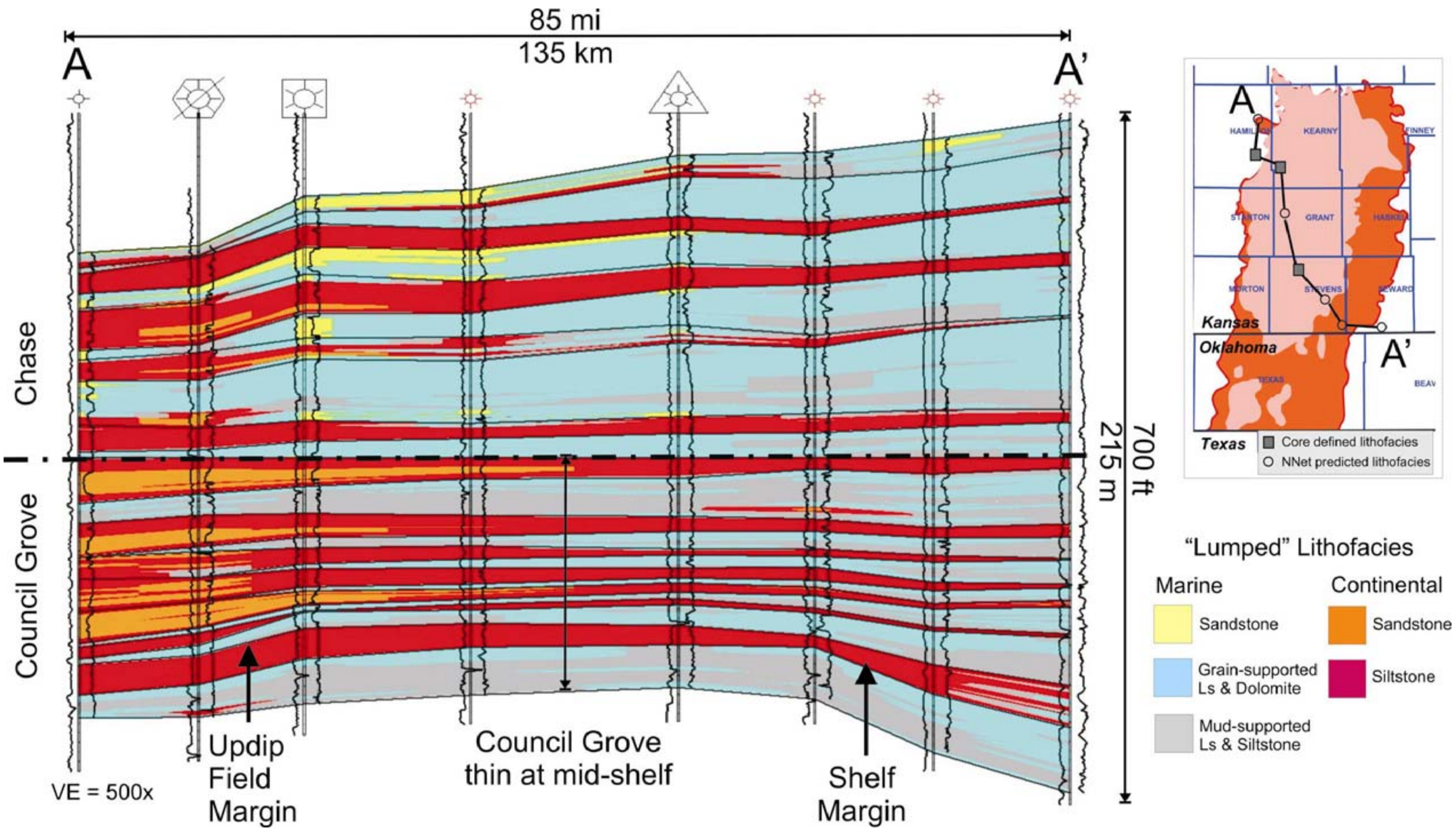

Figure 2.4. Stratigraphic cross-section of the Chase and Council Grove groups with the top of Council Grove as the datum. At wells, color-coded "lumped" lithofacies are those predicted by neural network models (small well symbols) or from core (large symbols) and are interpolated in Geoplus Petra™ between wells. Council Grove is thinnest at a mid-field (mid-shelf) position. Log curves are gamma ray (left) and corrected porosity (right).

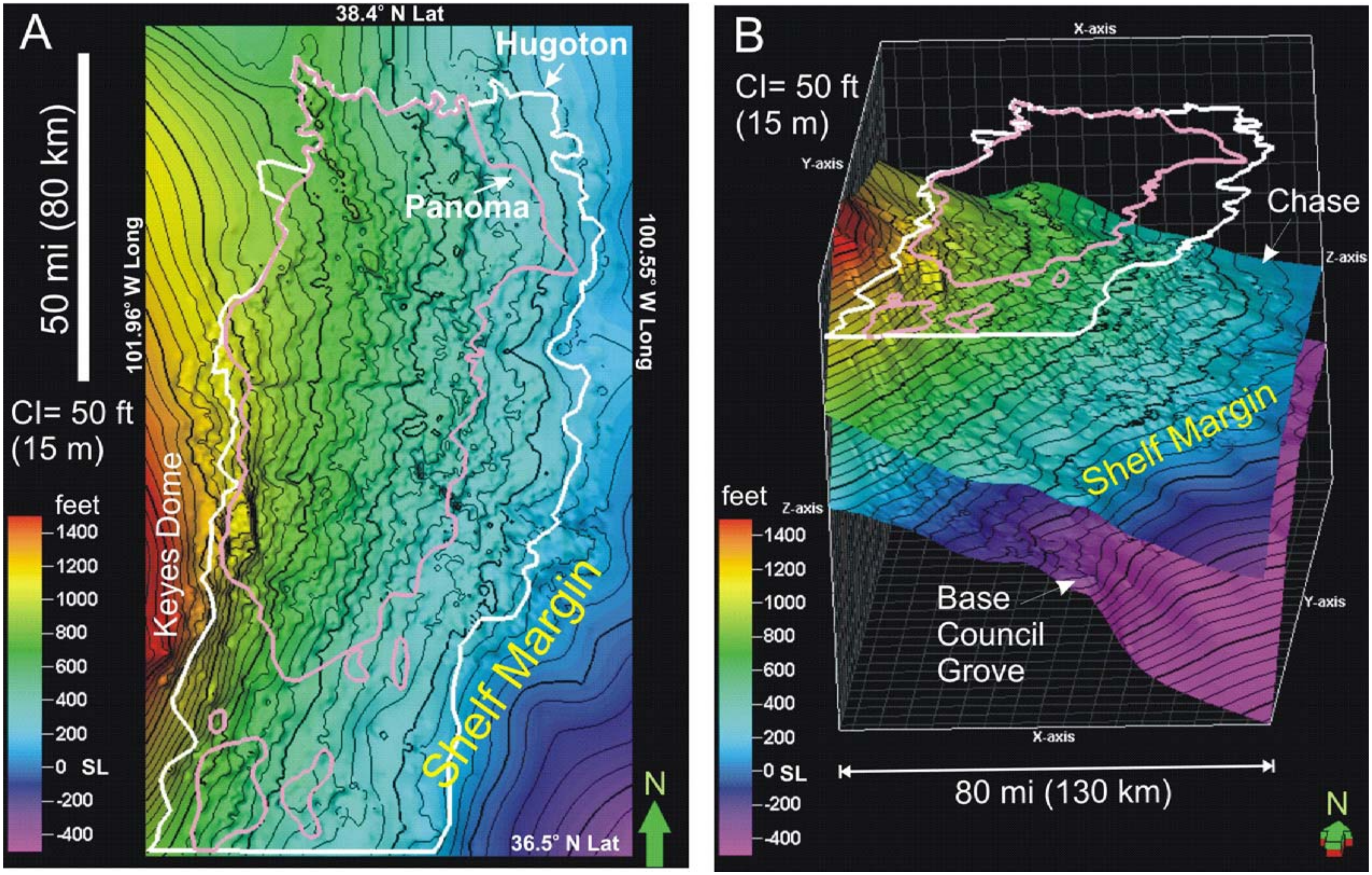

Figure 2.5. (A) Present day structure of the top of the Wolfcampian reservoir (top of Chase) is mostly a function of eastward tilt during the Laramide orogeny. Note the "shelf margin" or area of steepened slope at the southeast margin of the Hugoton field outline. (B) 3-D view of the same area. Present day structure on the top of the Chase and base of Council Grove.

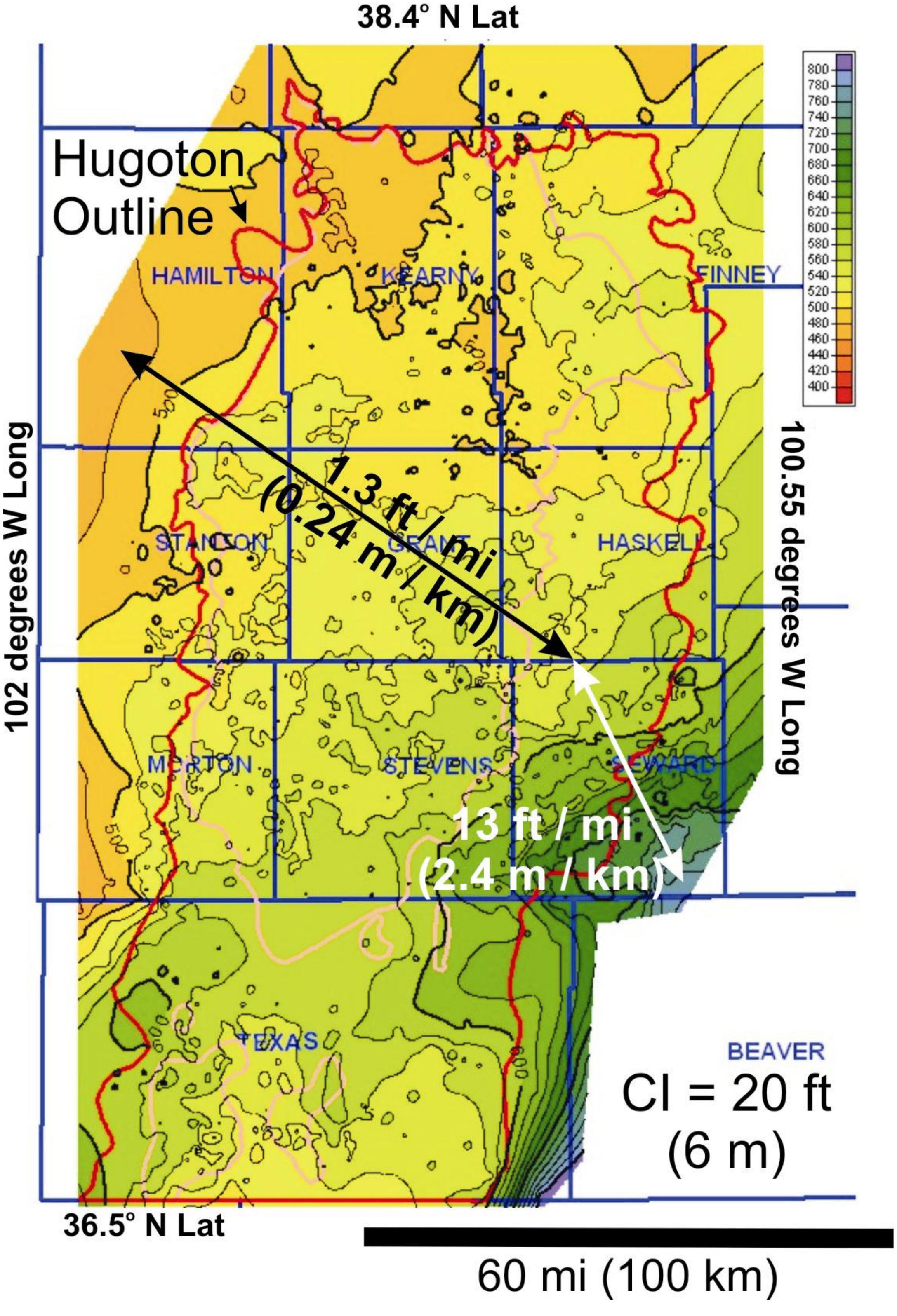

Figure 2.6. Isopach of the Wolfcampian reservoir (top of Chase Group to base of Grenola Limestone, Council Grove Group). Wolfcampian rate of thickening increases by a factor of ten at the "shelf margin."