3-D AVO study in eastern Alberta*

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INTRODUCTION

The seismic technique called AVO (amplitude variation with offset) has recently gained widespread attention among explorationist because it promises to assist in the interpretation of subtle stratigraphic targets and to identify hydrocarbon-bearing rocks with more confidence. The first objective of this study is to undertake the analysis and interpretation of a 3-D seismic survey in eastern Alberta. A second objective is to examine the data set for AVO anomalies which may be related to hydrocarbons and lithologic events, such as salt, or other rock types that cause sudden changes in velocity.

HISTORICAL SUMMARY OF AMPLITUDE COMPUTATION

The first computation of amplitudes for reflection coefficients at oblique angles of incidence was performed by Knott in 1899. Zoeppritz in 1919 produced a similar set of relationships for displacement amplitude. In 1940 a article was published by Muskat and Meres which showed the variation in reflection and transmission coefficients as a function of angle of incidence. These calculations were made using a typically wrong geophysical assumption that the Poisson's ratio of the bounding media were equal. In 1955 Koefoed found that by changing Poisson's ratio in the two bounding media, large changes of amplitude as a function of angle of incidence resulted. Koefoed observed that reflection coefficient is a function of; P-wave velocity, density, offset and Poisson's ratio. His results (Figure 1) demonstrated the influence of offset and Poisson's ratio on reflection amplitude (Wren,1984). This behavior is predictable and is a result of mode conversion at the boundary as a function of angle of incidence and the P and S-wave velocities above and below the boundary. Koefoed predicted in a more remote future it may be possible to draw conclusions concerning the lithologic nature of rock strata from the shape of the reflection coefficient curves (Ibid,1984).

In 1982 Ostrander demonstrated that the "remote future" had arrived when he presented his paper at the SEG meeting. From this work Ostrander (1984) concluded that: 1) Poisson's ratio has a strong influence on changes in reflection coefficient as a function of angle of incidence, 2) analysis of seismic reflection amplitude versus shot to group offset can in many cases distinguish between gas-related amplitude anomalies and other type of amplitude anomalies.

It should be remembered that the amplitude will take a large jump at the critical angle. Further the amplitude will increase with offset (either positive or negative) if the change in Poisson's ratio is in the same sense as the change in velocity. If the change in

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Poisson's ratio is opposite to the change in velocity, the amplitude will decrease with offset (either positive or negative).

In summary Poisson's ratio defines the shear velocity which controls amplitude. Therefore the pore fluid defines amplitude and by amplitude measurement it should be possible to define lithology on unstacked data.

GEOLOGICAL SETTING

The study area is located in eastern Alberta, (Figure 1) but due to the confidential nature of the seismic data a precise location has not been indicated. The zone of interest for this study area is the Lower Cretaceous Mannville group which has been studied regionally by Jackson (1985). Local geology has been examined by Hayes (1986), Hopkins et al (1982,1987), Hopkins (1987) and Taylor (1984). The study area is south of a Lower Mannville erosional feature called the Bellshill Lake Channel as indicated in Figure 2 (Ferguson,1989). Clastic sediments from the Pembina erosional high were deposited as Basal Quartz fluvial sands with a thickness of up to 60 metres in the Edmonton and Bellshill Lake Channels (Jackson,1985).

Succeeding the channel deposition, the eastern Alberta area was flooded by a southeasterly transgression of the Boreal Sea (Ferguson,1989). Lacustrine sedimentation occurred in lowlands in the former Edmonton channel and these sediments form the upper Basal Quartz Formation in the study area. The upper Basal Quartz consist of silts, shales and coarsening-upward progradational sands. There is also some fining-upward sands which were interpreted to be tidal channels (Figure 3) in an estuarine environment (Jackson,1985). Southward transgression of the Boreal Sea continued, resulting in coastal plain deposition in the study area.

In the study area, the Lower Mannville group consists of a two-lobed shaped basin cut into the Paleozoic sediments. The formation of the basin in this area may be due to collapse from salt dissolution, structural movement, mechanical erosion or solution erosion (Ferguson,1989). The basin was filled with 60 metres of lower Basal Quartz sand, which was overlain by 60 metres of shales, silts and linear channel sands of upper Basal Quartz Formation (Ibid,1989). A coal marker forms a local cap of the Lower Mannville.

There are a variety of names given for the Lower Cretaceous units (Figure 5) but the term lower Basal Quartz was used to identify the basal sand channels. The term upper Basal Quartz was used for the isolated channel sand in shale and silt deposited above the lower Basal Quartz. The Ostracod Formation was not identified in the study area so Glauconite sands could not be distinguished from the upper Basal Quartz channel sands.

DATA BASE

The CREWES Project has obtained a 3-D seismic survey from eastern Alberta. The survey covers an area of 4 kilometres x 6 kilometres and used dynamite as the seismic source. The geometry of the survey consists of 20 east-west receiver lines at 300 metre spacing and 11 north-south source lines at 360 metre spacing. This forms a 30 metre x 30 metre 3-D gather bin. If the seismic is picked on every line then there are approximately 20,000 control points for each horizon.

RESEARCH OBJECTIVES

The following research objectives are proposed:
1) reprocess data set with emphasis on amplitude preservation
2) identify AVO anomalies as a function of azimuth and offset for Lower Cretaceous interval.
3) detailed mapping of 3-D distribution of stratigraphic units
4) forward modeling using converted waves (P-SV) to test for lithologic discrimination

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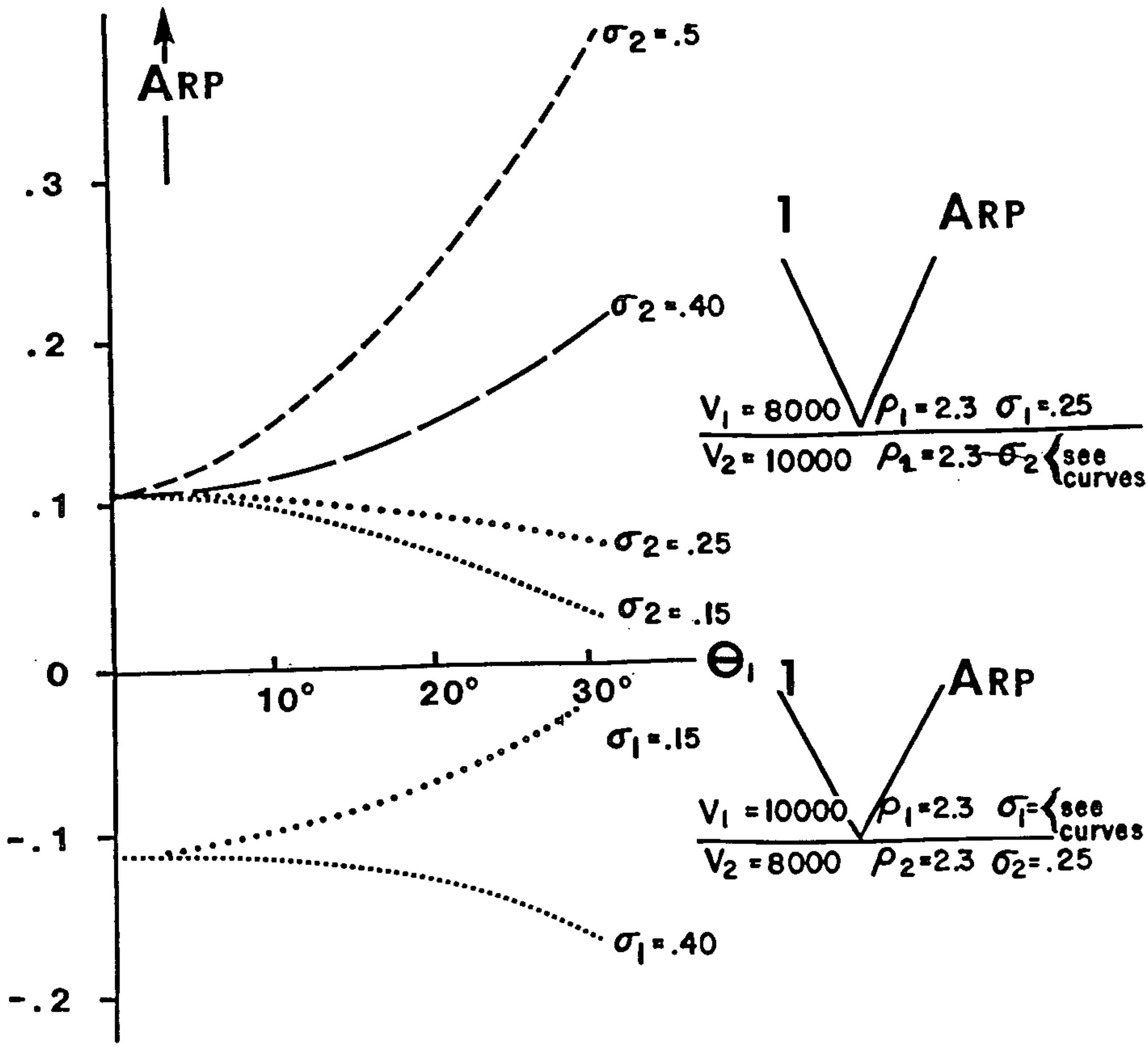

Fig. 1. The relationship between offset and Poisson's ratio in determining the reflection coefficient (Koefoed, 1955)

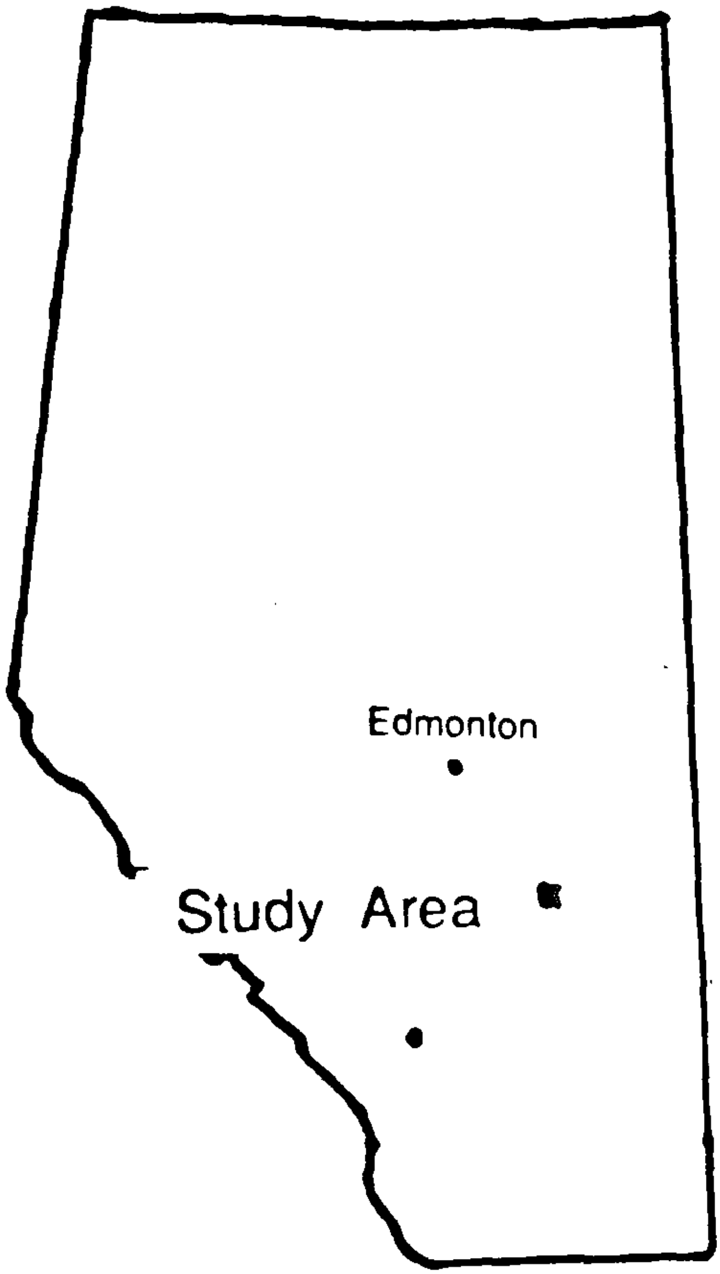

Fig. 2. Study area

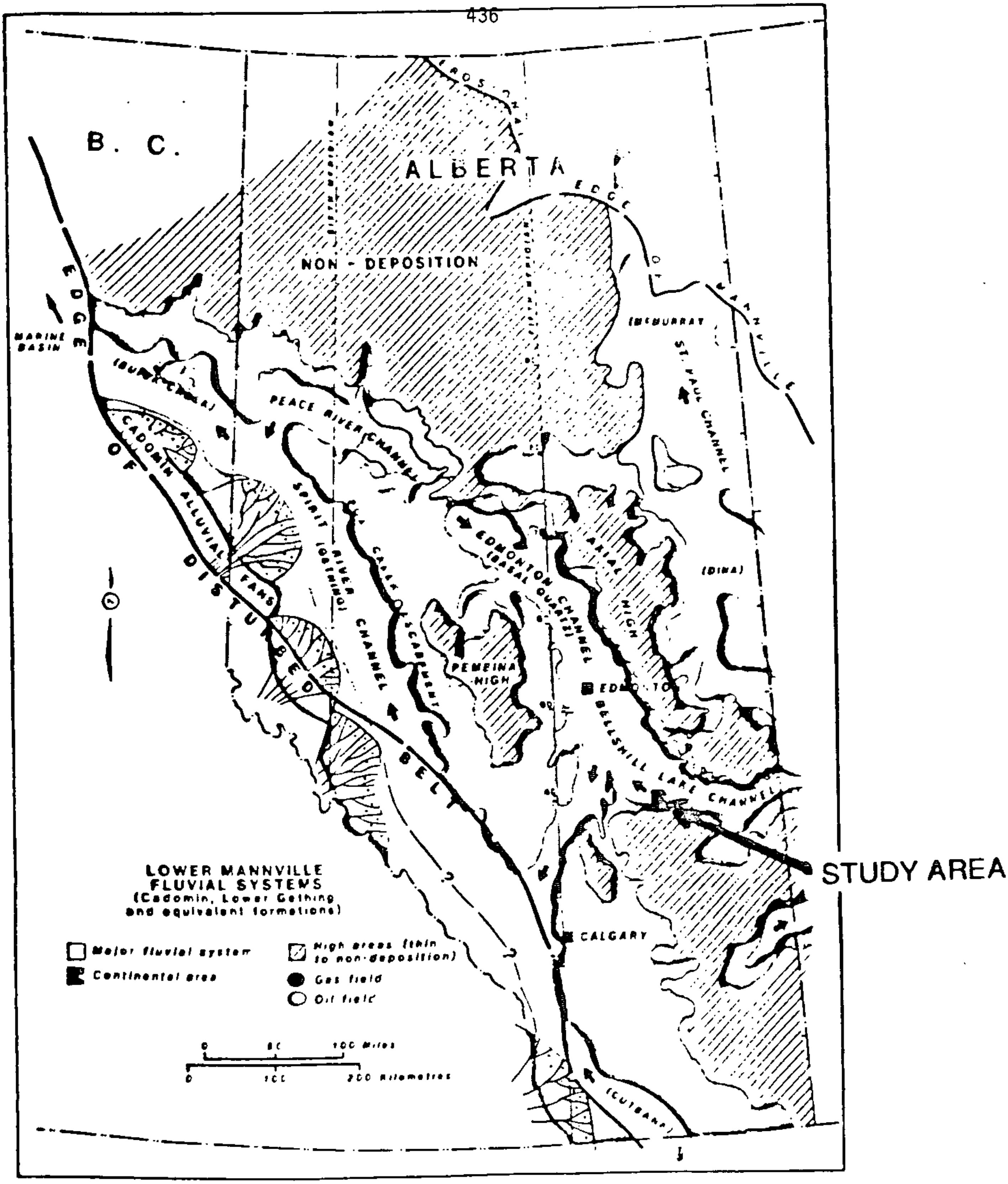

Fig. 3. Lower Mannville fluvial system (Jackson, 1985)

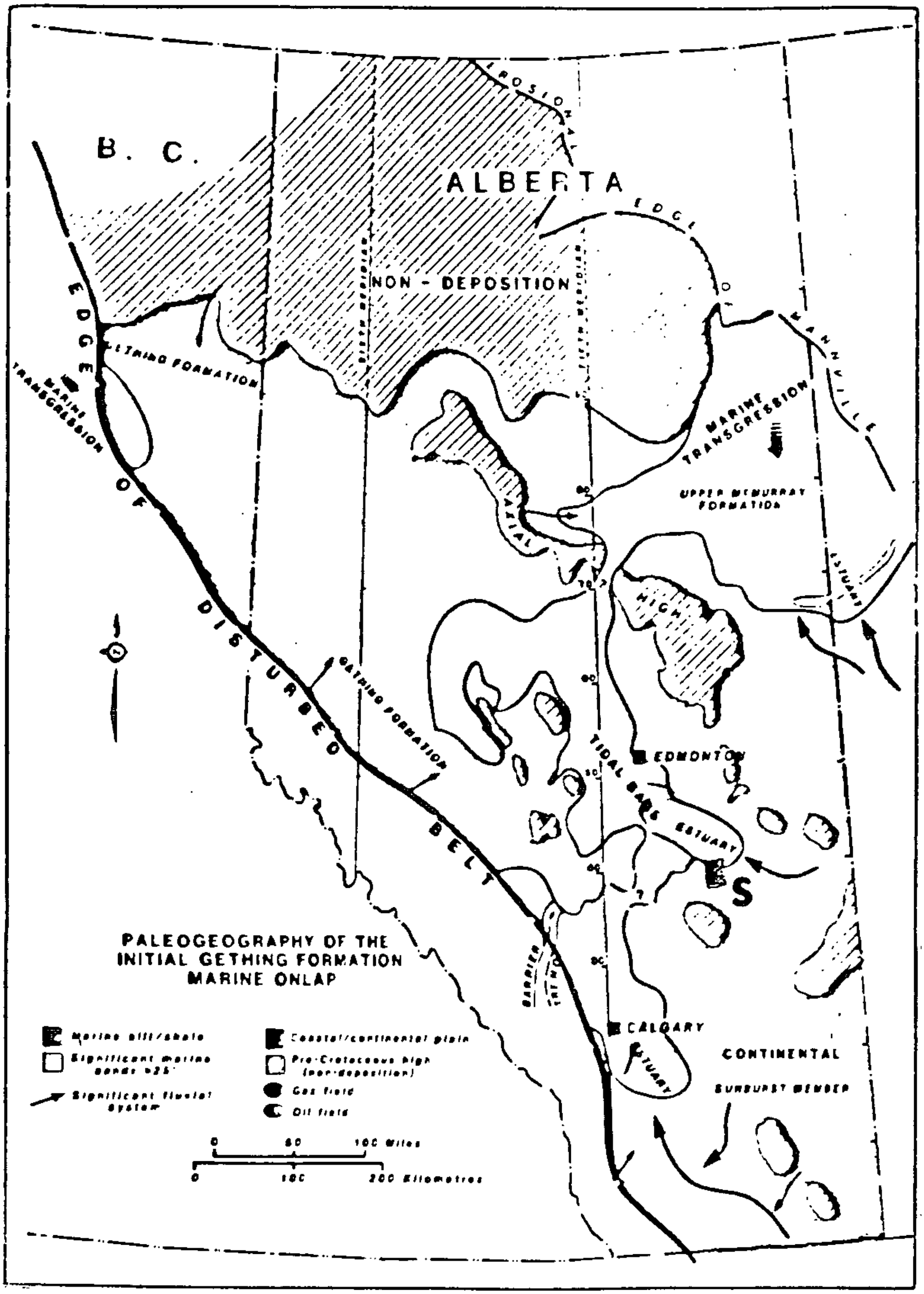

Fig. 4. Paleogeography of upper Basal Quartz (Jackson, 1985)

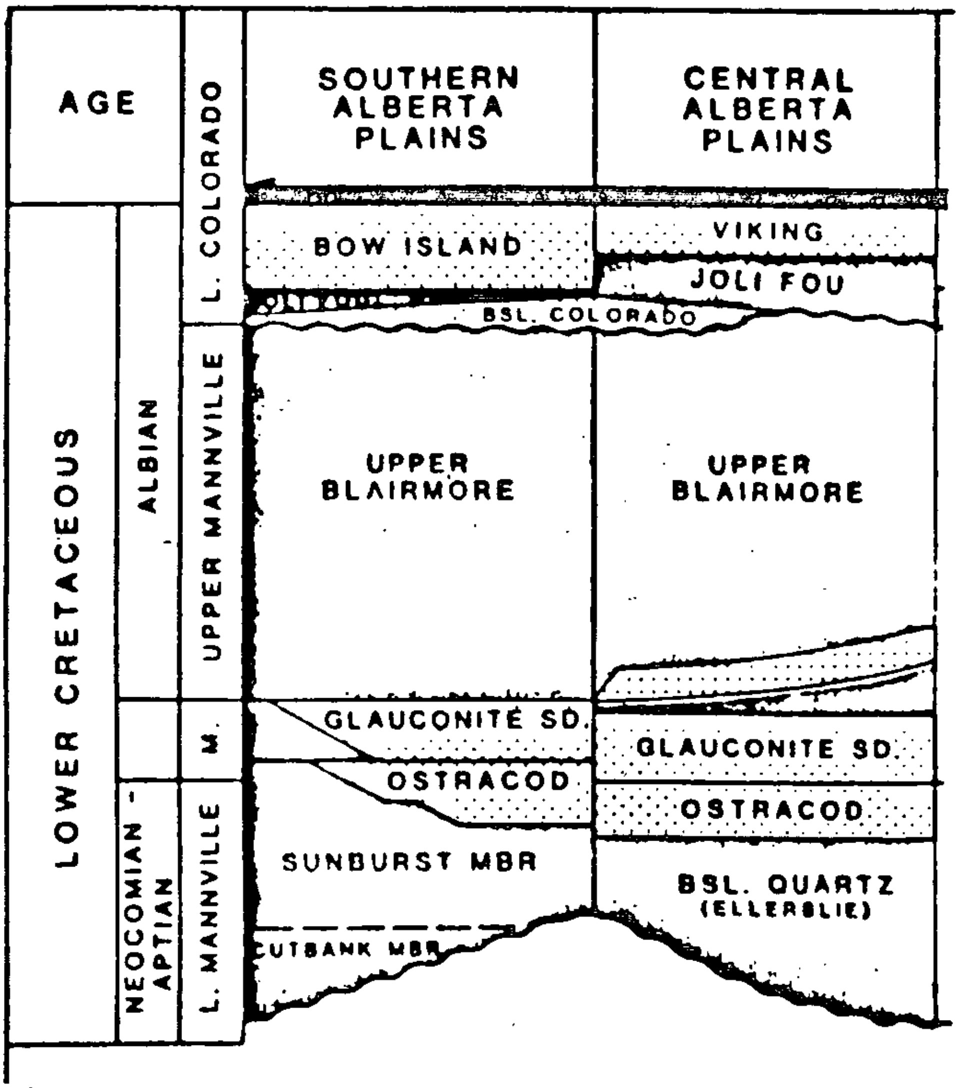

Fig. 5. Correlation chart (Jackson, 1985)