Statistical Estimation of the Apex of a Sediment Distribution System from Paleocurrent Data

P. E. Jupp, B. D. Spurr, G. J. Nichols, and J. P. P. Hirst

Precise statistical models are proposed for the distribution of paleocurrent directions in distributary systems. These models are based on a von Mises distribution for directions of paleocurrents in a system. The method of maximum likelihood is used to obtain an estimated position and confidence regions for the apex of the system. Both axial data (where only the trend of the paleocurrent is known) and directional data (where the direction of paleoflow is known) can be used. These models have been applied to two fluvial distributary systems in flat-lying Miocene deposits in the Ebro Basin, northern Spain. The estimate of the position of the apex of one of these systems is in good agreement with the position at the basin margin predicted from sedimentary facies information. The estimate of the position of the apex of the second system lies outside of the sedimentary basin; this result is considered to indicate that the distributary system had several feeder points along the basin margin, a situation which is predicted also from facies distributions. This statistical procedure can be used successfully on small data sets of around a hundred paleocurrent readings provided that they are scattered evenly across the area or lie in a wide arc.

KEY WORDS: directional statistics, distributary systems, maximum likelihood, paleocurrent, von Mises distribution.

DATA

Introduction

Paleocurrents in sedimentary rocks are used extensively as aids in the analysis of sedimentary basins and the development of paleogeographic reconstructions. By analyzing the direction of flow in fluvial paleochannels, deltaic systems, and turbidites, the sedimentary facies that may be expected both upstream and downstream may be predicted. It is also possible to indicate where the source of the sediments lay. Reconstructions developed using paleocurrent data are...

1Manuscript received 23 June 1986; accepted 21 October 1986.
2Department of Statistics, University of St. Andrews, St. Andrews, Fife, Scotland KY16 9SS.
3Department of Geological Sciences, University of Liverpool, P.O. Box 147, Liverpool, England L69 3BX.
4B.P. Petroleum Development Ltd., Kirklington Road, Eakring, Notts, England.
important in exploration for mineral deposits (e.g., gold and tin placer deposits) and in petroleum exploration (e.g., the trend of channel sandstone reservoirs).

Such paleogeographic reconstructions are often simplistic and limited to general statements about the direction of flow and probable position of the source area. In some cases, data do not allow further conclusions to be drawn, but where more complete data sets are available, further deductions about sedimentary processes and paleocurrent patterns may be possible.

Earlier statistical approaches to paleocurrent analysis have concentrated generally on calculation of the mean directions and subsequent analysis of variance (e.g., Olson and Potter, 1954; Watson, 1966). These methods assist in the analysis of the direction of flow, the degree of divergence of flow, and the determination of differences and/or similarities between data sets. Paleocurrent data are used frequently in large scale paleogeographic reconstructions (e.g., Tanner, 1955; Kumar and Bhandari, 1973) as a means of predicting relative positions of facies belts and basin margin, but only in a semiquantitative way.

Methods used hitherto have tended to be rather ad hoc. The principal advantages of proper statistical modeling are that (i) the method is objective, (ii) confidence regions for the estimates can be found, and (iii) the fit of the model to the data can be tested.

The method described here has been developed using data from fluvial distributary systems, but could be applied to any geological situation where a convergence of flow directions occurs. It allows the estimation of the position of the apex of any distributary system.

Geological Setting

Early Miocene deposits of the northwestern part of the Ebro Basin, northern Spain (Fig. 1) form part of a thick sequence of continental molasse deposited in the southern foredeep of the Pyrenees Mountains. Most sediments are fluvial and lacustrine, the latter being predominant in the center of the basin. Fluvial sediments in the study area are considered to be deposits of two fluvial distributary systems (Hirst and Nichols, 1986, Nichols, 1987). The distribution of facies belts in the two systems strongly indicates that their most proximal parts, the apices of the two systems, lay at or near the northern margin of the basin. Paleocurrent data have been used here in an attempt to locate these apices more precisely.

Data Collection

The paleocurrent data were collected in the field using a standardized set of procedures. Exposures generally consist of bodies of medium to coarse sandstone which are the fill of fluvial paleochannels. These sandstone bodies occa-