Magnetic Reversal Stratigraphy in the Late Oligocene succession of the Ebro Basin, near Fraga, Province of Huesca, Northern Spain

P. F. FRIEND (1); S. A. BRAZIER (2); L. CABRERA (3); K. W. A. FEISTNER (1) and J. SHAW (4)
(1) Department of Earth Sciences, University of Cambridge, Downing St., Cambridge CB2 3EQ (England)
(2) British Geological Survey (Hydrocarbon and Marine Surveys Directorate), «Southpark», 19 Grange Terrace, Edinburgh EH9 2LF (Scotland)
(3) Departamento de Geología Dinámica, Geofísica y Paleontología. Universidad de Barcelona. Fac. Geología, 08028 Barcelona (Spain)
(4) Department of Geological Sciences, University of Liverpool, P. O. Box 147, Brownlow St., Liverpool, L69 3BX (England)

SUMMARY

A palaeomagnetic investigation of an outcrop section in Late Oligocene, non-marine mudstones, sandstones and limestones is described. The section was chosen as representative of the outcrops of the more central parts of the Ebro basin, northern Spain. It turns out to be impossible to measure an early remanence in the limestones that are an important rock type of the basin centre. However distinct magnetic components, thought to be early, can be measured in many of the mudrock samples. Seven reversal events occur within the 145 m thick section, and define six magnetic polarity intervals. Assuming a relatively steady stratigraphic accumulation rate, the thicknesses of the magnetic intervals correspond to the time durations of the (global) magnetic polarity time-scale. The sequence of thickness intervals in our section is not long or distinctive enough to allow us to suggest an unique correlation with the global sequence, but we suggest two possible alternative correlations. The alternatives imply stratigraphic accumulation rates of 0.04 and 0.07m/1.000 years.

STRATIGRAPHIC INTRODUCTION AND OBJECTS

The Ebro basin is a foreland basin that developed in response to crustal loading during the Tertiary evolution of the Pyrenees (Fig. 1). The

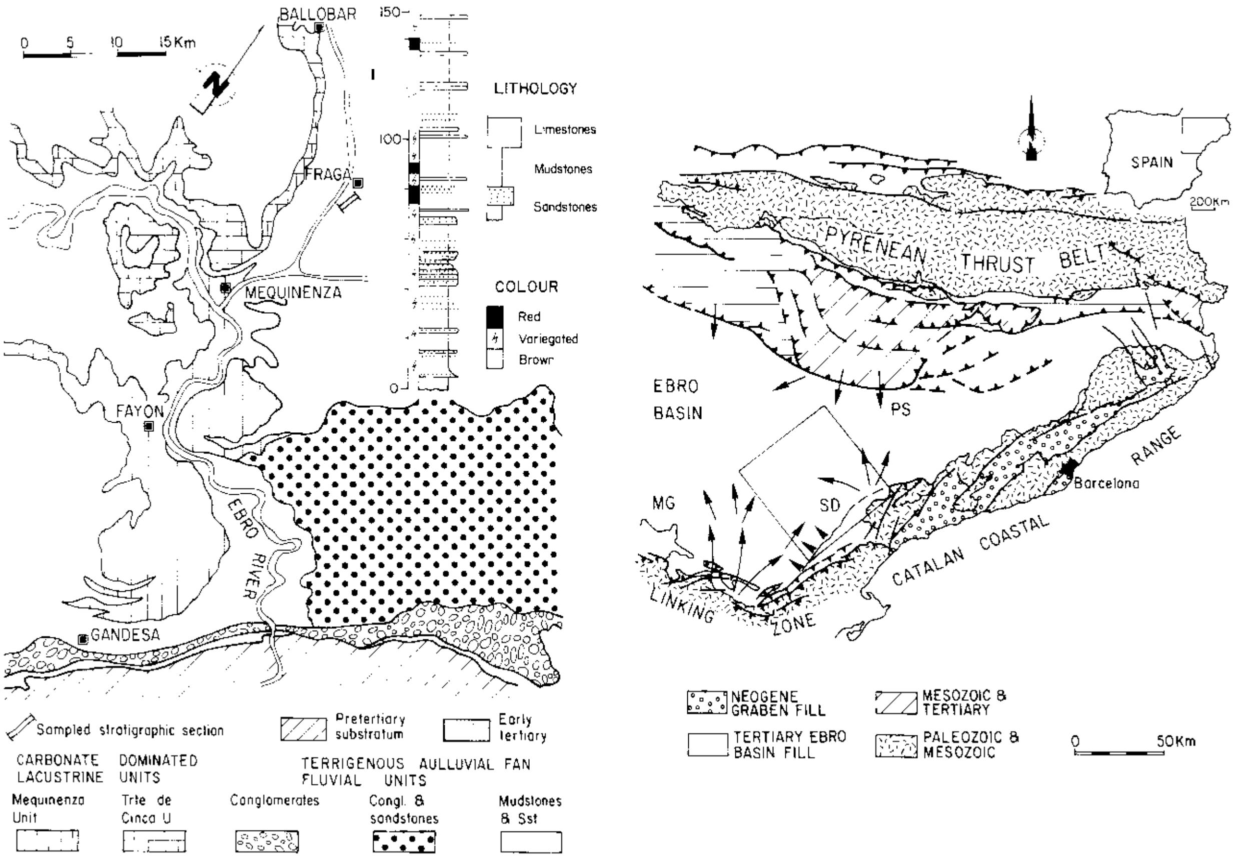

Fig. 1. General location and geology of the central and eastern parts of the Ebro basin and larger scale map of part of the eastern Ebro Basin outlined on the general map showing the location of the Fraga section, and the general outcrop geology of its surroudings. A summary log of the section is also presented. MG:Matarranya-Guadalupe alluvial system. PS: Pyrenean alluvial systems. SD: Scala Dei alluvial system.

main evidence for this is the general northward increase in the thickness of the basin-filling sediments, from about 1 km in the central areas (including the Fraga area reported here), to between 3 and 4 km below the southern Pyrenean thrust front (Riba et al., 1987).

The Ebro basin arose as a well defined entity during the Oligocene, when the southern thrust sheets of the Pyrenees started to emerge to form its northern margin, and its southern margin also became active tectonically (Puigdefàbregas et al., 1986).

The surface outcrops across most of the basin are of sediments of Oligocene and Miocene age, formed in river and lake environments (Fig. 1).

A number of river systems carried sediment from different parts of the basin margins towards its centre. The Late Eocene-Early Oligocene Scala Dei System built out from the south-west end of the Catalan Coastal Range; the Oligocene-Miocene Matarranya-Guadalupe System extended from the linking zone between the Catalan Coastal Range and the Iberian Range in the south, and Oligocene-Miocene systems built from the Pyrenees in the north (Cabrera et al., 1985; Hirst and Nichols, 1986; Nichols, 1987). In all these cases, conglomeratic alluvial fan sequences accumulated along the basin margins, and passed distally into distributive fluvial facies. These facies consist of thick mudstone dominated sequences with interbedded conglomeratic and sandstone bodies from 1 m up to 10 m thick. Both vertical and lateral accretion are recorded in these channel deposits which show ribbon and sheet geometries.

These river systems interdigitated, towards the basin centre with a central zone where playa-lake muds, carbonates, gypsums and coals formed (Cabrera, 1983; Cabrera et al., 1985; Friend, et al., 1986; Nichols, 1987; Cabrera and Sáez, 1987). In the SE Ebro Basin, these facies make up sequences up to 600 m thick (Los Monegros lacustrine system) (Cabrera, 1983; Cabrera and Sáez, 1987). This study was carried out in the transitional area between one of the river systems coming from the Pyrenees and the Los Monegros lacustrine system of the central zone (Fig. 1).

The dating of the non-marine, Oligocene and Miocene deposits depends largely on the vertebrate fossils they contain, particularly the mammal microfossils. These are of sufficiently great biostratigraphic interest, in terms of the evolution of European terrestrial faunas, that the Ramblian and Aragonian nonmarine stages have been defined in north-central Spain (Daams et al., 1987). More specifically, in the study area, some twenty mammal microfossil localities have been found and this has suggested a Late Oligocene-Early Miocene biozonation, and the tentative proposal of a mammal stage stratotype (Agusti et al., 1988b). However it has proved difficult to correlate these faunas with other successions, particularly those with globally established marine biostratigraphy.

Our objects in working on the magnetic reversal stratigraphy in the Ebro basin have been

1) to establish local rates of stratigraphic accumulation as a means of analysing the basin growth,
2) to investigate the relationships between these rates and the processes of river sedimentation,
3) to establish correlation between the terrestrial and the marine biostratigraphy.

This paper will focus on the first aim.

THE SECTION AND ITS SEDIMENT TYPES

The section we report on here starts some 1.5 km south-east of the old bridge across the river Cinca, in the town of Fraga, Province of Huesca, Spain (Fig. 1). Map references and latitude and longitude of the base of the section are BF 797 998 and 0 20 E, 41 31 N. A detail sedimentary log of the section forms part of a study (Cabrera, 1983) of the basin-centre sediments in this part of the Ebro basin.

The 145m section consists largely (63 %) of mudstone, with varyig colour (brown or red), and content of silt. This mudstone was the main sediment type that we sampled as oriented blocks, and most of our successful measurements were of this material. Brown fine to medium-grained sandstones make up about 33 % of the section, and sometimes provided successful measurements. These sandstones outcrop as thin (a few cm) sheets, or as larger sandstone bodies up to 3 m thick.

Limestones, some 0.20 m to 3 m thick, formed only 4 % of our Fraga section, and are mainly present in its top 30 m. However similar limestones are the dominant sediment types exposed in some of the other basin centre sections that we sampled extensively within 20 km of Fraga. We sampled them widely because they tend to outcrop strongly, provide good material for detaching oriented blocks, and had shown measurable natural remanence during our early exploratory work. We were therefore disappointed to find, on using the thermal demagnetisation routines described below, that the limestones generally lack a component of remanence that is stable. We have concluded that the limestone remanence resides in the brown oxide patches and veins that are typical of most of the samples, and we suggest that this brown material results from late stage oxidation of the pyrite which is often abundant. We have therefore abandoned the measurement of limestones from these sections.

MEASUREMENT ROUTINE AND ANALYSIS

Oriented blocks were collected at «vertical» stratigraphic intervals averaging about 2 m. This sometimes involved excavation below the surface.

The blocks were chosen large enough to provide at least three cores which are 9 mm in diameter, and at least 1 cm in length. Oriented cores for measurement were prepared in the workshop in Cambridge by dry drilling using a slowly rotating coring bit. This was formed from a stainless steel tube, to avoid magnetic contamination, with teeth individually hand cut and set to achieve maximum self-clearing of the cylindrical incision.

All the measurements were made using the cryogenic magnetometer designed and run in the Department of Geology, University of Wales at Cardiff. We found that thermal demagnetisation of the samples produced relatively clear separation of components of the remanence, whereas alternating field demagnetisation proved to be ineffective. We used a measurement routine involving steps of 100° C, from 0° C to 500° C. A lower maximum temperature would not have resulted in complete demagnetisation, and larger steps would have resulted in loss of component information. Each core took about 3 hours to measure.

We routinely plotted the movement of the magnetic vectors that occurred during thermal demagnetisation, using both stereographic (direction), and vector (direction and intensity-Zijderveld, 1967) plots. The stable magnetic directions were then estimated from these plots (eg. Fig. 2). Our statistical treatment of the three or more stable cores from each site, used the method adopted in other recent studies of reversal stratigraphies (eg. Johnson and others, 1985), whereby sites were classified as class A, class B, or rejected, depending on the degree of agreement between the directions from the different cores.

RESULTING MAGNETOSTRATIGRAPHY

We measured cores from 34 sites scattered through the 145 m thick Fraga section (Figs. 3 and 4). Our stereographic and vector results yield exactly similar polarity intervals, even though the actual directions vary in detail. Here we present the vector data, consisting of 33 class A sites, and 1 class B site. Samples from 9 other sites were measured but showed no stable component during demagnetisation from one temperature to another, and were therefore rejected.

Fig. 3 shows the declination and inclination averaged for each of the 34 acceptable sites. We also present the VGP (Virtual Geomagnetic Polarity) latitude, which is the present latitude of the pole calculated from the remanence at each site. Our data locate seven reversal events in the

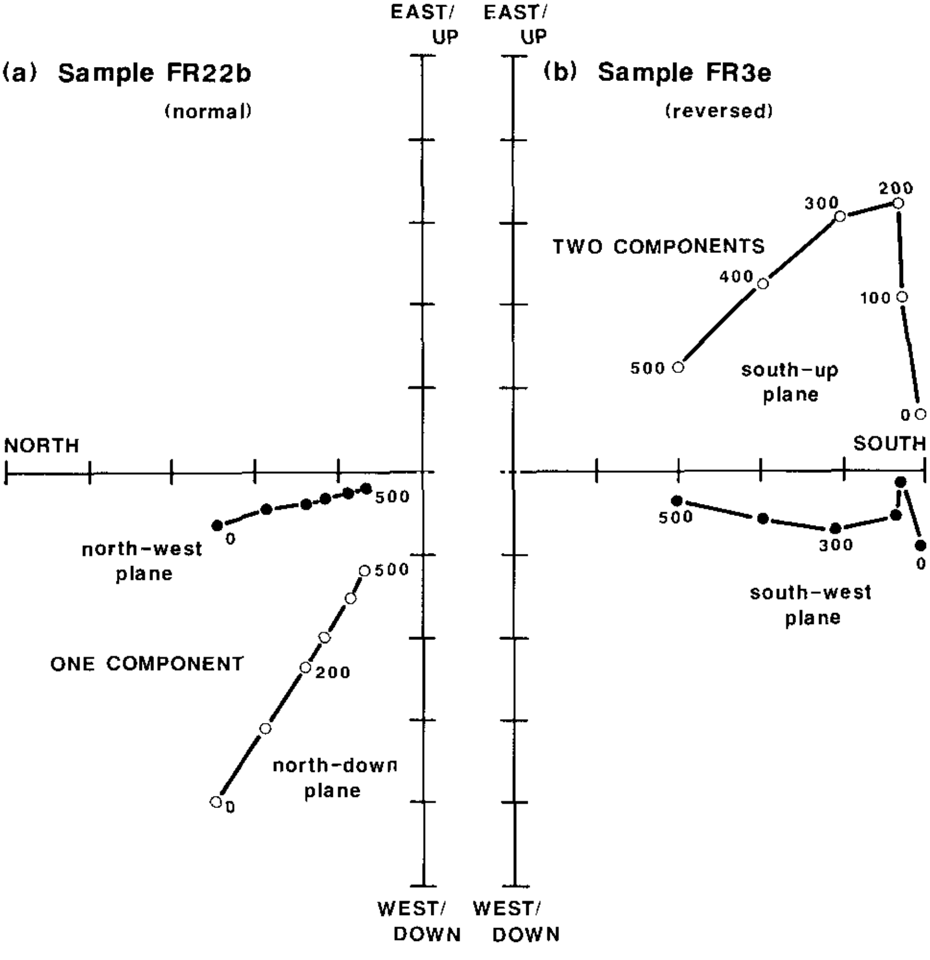

Fig. 2. Components of remanent magnetic intensity along three orthogonal directions within and perpendicular to bedding, for two samples. Sample FR22b shows one (north-down, or normal) vector of remanence, decreasing steadily when demagnetised by heating in 100° C steps from 0° C to 500° C. Sample FR 3e shows two components of remanence, under the same demagnetisation treatment, and the higher temperature component is reversed (south-up).

section, and these define six polarity intervals. If we assume that the rate of stratigraphic accumulation of the section is relatively steady, we can then examine the thickness of our sequence of polarity intervals, and compare them with the (global) magnetic polarity timescale, as, for instance, reviewed by Harland and others (1982). The vertebrate biostratigraphy of the area (Agusti et al., 1988) suggests that the section lies somewhere in the Late Oligocene, and it is immediately apparent, that our sequence of po-

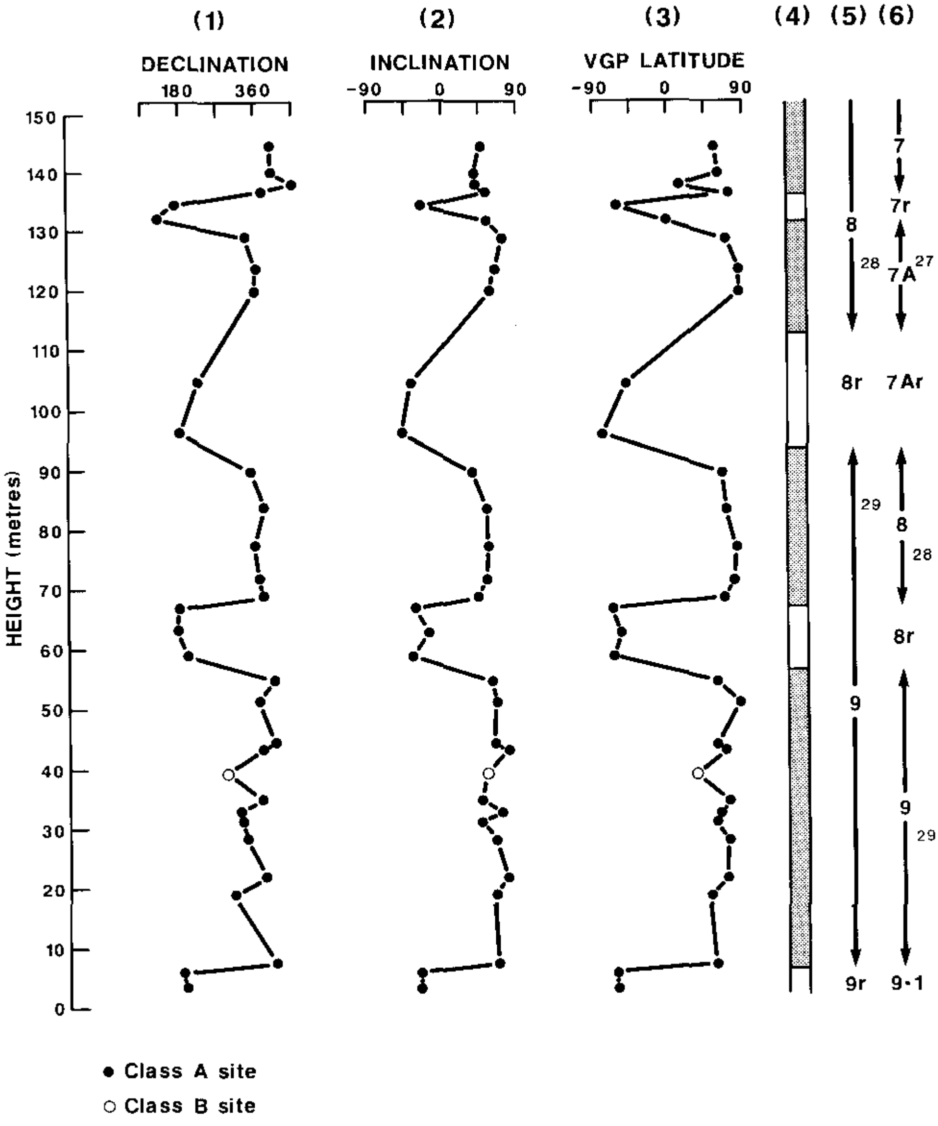

Fig. 3. Magnetic directional data for sites sampled at intervals up the Fraga section, located and described in this paper. Magnetic components have been selected by examination of vector plots (see Fig. 2) of measurements made during thermal demagnetisation. Columns represent 1) declination; 2) inclination; 3) virtual geomagnetic pole latitudes based on 1) and 2); 4)intervals between magnetic reversals with normal intervals shaded, and reversed intervals unshaded; 5) and 6) alternative correlations with global magnetic scale as outlined and labelled by Harland and others (1982). Ages from the latter publication are placed approximately, beside columns 5) and 6).

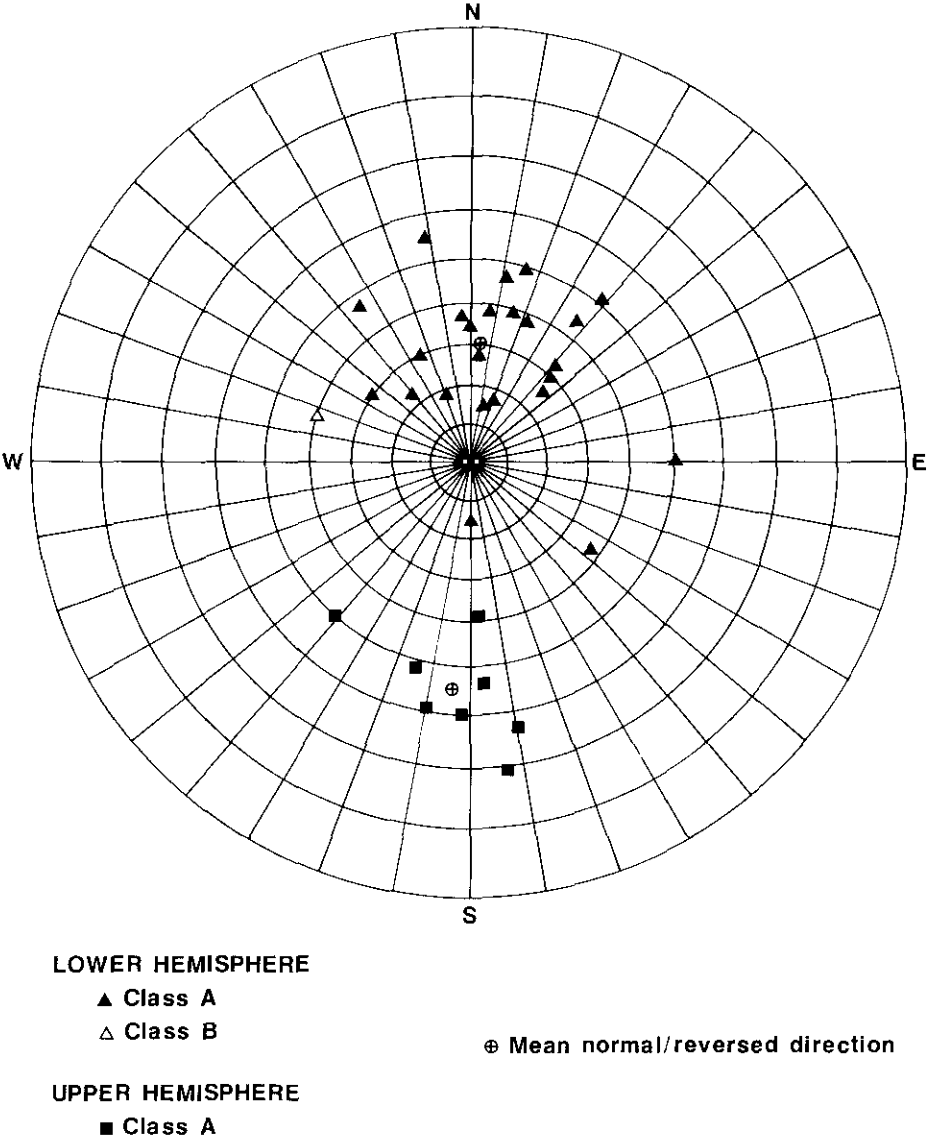

Fig. 4. Stereographic projection of means of each of 34 sites in Fraga section. Class A and Class B sites, upper hemisphere and lower hemisphere directions are distinguished. Means of normal and reversed directions are shown, and are very nearly diametrically opposite.

larity intervals is not long enough, or distinctive enough to provide a convincing correlation. We therefore suggest two alternative possibilites in Fig. 3.

ESTIMATES OF RATES OF STRATIGRAPHIC ACCUMULATION

Our Fig. 3 shows two possible correlations of our polarity intervals using the chron terminology of Harland and others (1982). Using also the ages for these chrons suggested by Harland and others (1982), we arrive at average stratigraphic accumulation rates for the whole of our section of 0.07 m/1.000 years, and 0.04 m/1.000 years for the two correlations. These rates are at the low end of the ranges quoted from other foreland basins (Johnson and others, 1985; Johnson and others, 1986; Homewood et al., 1986), and this shows that the Fraga area was one of only moderate subsidence. In the introduction to this paper we used basin thickness totals to argue that the Fraga area subsided moderately compared with the area of the Pyrenean front.

Acknowledgements

We offer our sincere thanks to the United Kingdom Natural Environment Research Council who supported Sarah Brazier and Karl Feistner while they sampled and measured the material, and to Dr. C. Puigdefàbregas, and the Servei Geològic de Catalunya for field support, during this investigation of Ebro basin palaeomagnetism. All staff and colleagues at Cardiff contributed to the excellent running of the measurement laboratory. Professor Oriol Riba has provided a base for the stratigraphic work on the Ebro basin, in his Department of the University of Barcelona.

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Received 10 Feb. 1988.
Accepted 13 June 1988.