MULTISPECIMEN PALEOINTENSITY DETERMINATION FROM CRETACEOUS CARIBBEAN IGNEOUS PROVINCE

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ABSTRACT

We report paleomagnetic results from Colombia for the Cretaceous. Samples from 15 sites north of Cali were related to age determinations of 92.5 ± 1.1 Ma from close localities. This age lies in the Cretaceous Normal Superchron and is of special interest due to its long period of normal polarity and due to its large and contradictory range of paleointensity values. From our directional investigation we obtained a Virtual Geomagnetic Pole (VGP) with a paleolongitude, Plon: 90.1°, a paleolatitude, Plat: 73.7° and a confidence interval α_{95}: 20.1°. The latitude coincides very well with the paleolatitude from a similar age from North America reported by Besse and Courtillot (2002). The multispecimen protocol provided six out of ten successful paleointensity determinations, which are equivalent to a Virtual Dipole Moment (VDM) of 2.3 x 10^{-22} Am^2 on average. This value is in good agreement with high quality data reported in Tauxe *et al.* (2013).

Keywords: Cretaceous Normal Superchron, Paleointensity

RESUMEN

Presentamos los resultados paleomagnéticos de Colombia para el Cretácico. Las muestras de 15 sitios al norte de Cali están relacionados con determinaciones de edad de 92.5 ± 1.1 Ma de localidades cercanas. Esta edad se encuentra en el Supercrón Normal Cretácico y es de especial interés debido a su largo período de polaridad normal y debido a su gran y contradictorio rango de valores de paleointensidad. De nuestra investigación direccional obtuvimos un polo virtual geomagnético (VGP) con una paleolongitud, Plon: 90.1°, una paleolatitud, Plat: 73.7° y un intervalo de confianza, α_{95}: 20.1°. La latitud coincide muy bien con la paleolatitud de una edad similar de América del Norte reportada por Besse y Courtillot (2002). El protocolo de multi especímen proporcionó seis de diez determinaciones de paleointensidad exitosas, que son equivalentes a un momento dipolar virtual (VDM) de 2.3 x 10^{-22} Am^2 en promedio. Este valor concuerda muy bien acuerdo con datos de alta calidad reportados en Tauxe et al. (2013).

Palabras Clave: Supercrón Normal Cretácico, Paleointensidad

Background

During the last 120 Ma the geomagnetic field underwent dramatic changes in its polarity. Epidodes of polarity reversals occur on various time scales, *e.g.*, chrons are on the order of 10^5 to 10^6 years, subchrons on the order of 10^3 to 10^4 years (Cox *et al*., 1964). Long stable polarity periods (several tenths of millions years) are called superchrons. The long superchron in the Cretacous, the Cretacous Normal Superchron (CNS), lasted from 120.6 to 83.0 million years (Channell *et al*., 1995; Cande, Kent, 1995). On the one hand, Tarduno and Smirnov (2001) suggest that the time-averaged field during the Cretaceous Normal Polarity Superchron was unusually high and stable. Some evidence of high field was also reported by Tauxe and

Staudigel (2004) from a study of submarine basaltic glass. On the other hand, systematic and high standard paleomagnetic surveys carried out on Cretaceous volcanic rocks may provide some decisive constraints on the existence of the Mesozoic Dipole Low (MDL) characterized by low absolute intensity (Prévot *et al*., 1990; Tanaka *et al.*, 1995). However, the duration and even the existence of the MDL is not estimated and understood (*e.g*., Goguitchaichvili et al., 2002; Tarduno, Cotrell, 2005). Most of the data for the Cretaceous comes from latitudes higher than 30° N, while few data come from low latitudes and South America (*e.g*., PINT06 database, Tauxe and Yamazaki, 2007). Also, dating of available data is still scarce. Most of the data is concentrated in the last 5 Ma while for the CNS few data exist. However, for an accurate description of the changes of the Earth's magnetic field a large collection of data from the CNS for Central America is indispensable. Depending on the study values range from 20 to139 ZAm^2 during the CNS (*e.g*., Tarduno *et al*., 2001; Prévot *et al*., 1990; Goguichaichvili *et al*., 2002; Qin *et al*., 2011). From studies of relative paleointensity Tauxe and Hartl (1997) and Constable et al. (1998) found a weak correlation between the intensity of the geomagnetic field and the length of polarity intervals. Tauxe (2006) got a similar conclusion based on a data collection of absolute paleointensities obtained from samples of submarine basaltic glasses. The Cretaceous is considered as a key period for the long-term evolution of the geomagnetic field as well as for the understanding of dynamo processes, which evoke these field variations. In order to gain a better understanding of the variation of the geomagnetic field during the CNS in Mesoamerica, we investigated volcanic rocks from Colombia, specifically from the cretaceaous Colombian igneous province.

Sampling and Rudiments of Local Geology

Volcanic rocks were taken from 15 sites near Cali in the Western Cordillera of Colombia (Fig. 1). The samples were oriented using sun and magnetic compass. Sinton et al. (1998) conducted $^{40}Ar/^{39}Ar$ radiometric dating of samples from different locations in the Caribbean platform, specifically in Colombia. Sinton *et al.* (1998) obtained an age of 91.7 ± 2.7 Ma (Pan6) from basalts of the Western Cordillera of Colombia, close to the sites where our sampling sites are located. This age coincides with another dating near Rio Bolo Blanco, made on picrite, of 93.21 ± 3.60 Ma (COL 354, Kerr *et al*., 2002). Summarizing, we used for our samples the average of these datings, 92.5 ± 1.1 Ma. We performed various rock magnetic measurements: backfield,

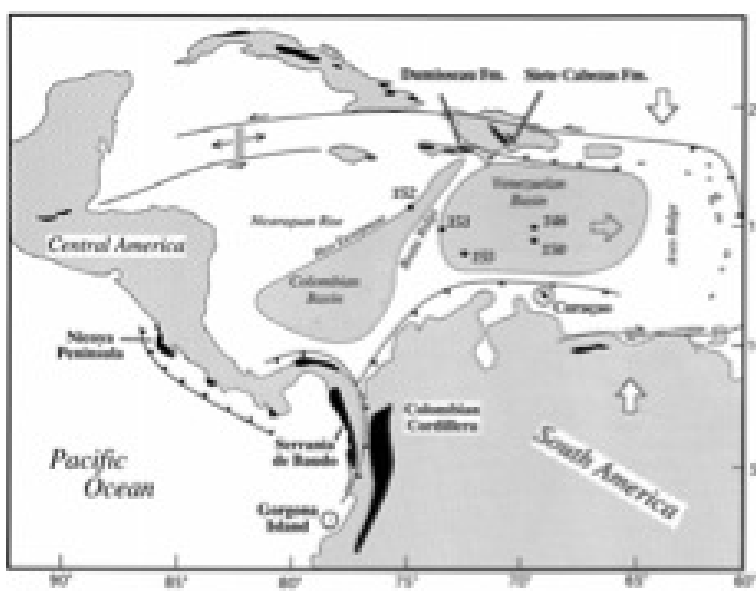

Figure 1. Schematic map of the Caribbean region. In black, parts of the obducted material are shown. The investigated site lies in the Colombian Cordillera. Figure from Sinton *et al*. (1998).

hysteresis and thermomagnetic curves to determine the type of magnetic mineral and grain size, and thermal stability of the remanent magnetic carriers. Furthermore, we determined the Virtual Geomagnetic Pole (VGP) from directions using alternating field (AF) and thermal (TH) demagnetization. Additionally, we determined the Virtual Dipole Moment (VDM) using the Thellier-Thellier technique with the Coe protocol (Thellier, Thellier, 1959; Coe, 1967), as well as with the multispecimen method by Dekkers and Böhnel (2006).

Magnetic Measurements

The thermomagnetic curves (magnetization versus temperature) show that the main magnetic component is (titanium) magnetite. Backfield curve measurements confirm a low coercivity magnetic mineral, which may be, magnetite or maghemite in agreement with the measurements of the thermomagnetic curves. The thermomagnetic curves are almost reversible or reversible indicating chemical stability of the magnetic materials. Measurements of hysteresis show that the coercivities range from 8.1 to 17.4 mT. These values could be indicative for grain sizes of multidomain to single domain, or mixtures of several grain sizes in a sample. Vector diagrams of the AF and TH demagnetized specimens show one main component plus a viscous component or a complex multicomponent behavior. Most specimens demagnetized with AF are demagnetized at low field strengths of about 40 mT and show a viscous component up to 6 mT on average. TH demagnetized specimens are in most cases unsuccessful. Directions were accepted if they met the following criteria: Maximum Angle Deviation, MAD $\leq$ 10°, angle of deviation, DANG $\leq$ 10°, and number of points for the fit line $n \geq 3$. We accepted 56 out of 85 specimens. All sites with less than 3 specimens were rejected as well as sites with a confidence interval of directions, $\alpha_{95} > 15°$. We obtained an average VGP with a paleolongitude, Plon: 90.1°, and a paleolatitude, Plat: 73.7° and α_{95}: 20.1° (Fig. 2). Individual VGPs and their average were compared with those of Besse and Courtillot (2002). Their synthetic VGP for 91.4 Ma for South America has Plat of 84.8° and Plon of 175.7° and, for North America Plat of 75.3° and Plon of 196.4°. In general, the latitudes match with those of Besse and Courtillot (2002). The latitude of one site differs by less than 5% from the latitude of South America. The average of the sites agrees better with the latitude of North America. In contrast, the longitudes vary between 44 and 147% of the value for South America. For the determination of the VDMs the Thellier-Coe method gave no successful results. Therefore, we applied the multispecimen protocol on 10 specimens. Three samples failed, because they gave negative intensities. In one case no value could be determined. The remaining six specimens show in general a linear behavior which gave a best linear fit with $R^2 = 0.77 \pm 0.21$ on average. The average paleointensity value of the six successful determinations produced an average of 8.8 ± 5.6 µT. This value is equivalent to a VDM of 2.3×10^{-22} Am^2, which is rather low, but in good agreement with other data from the same time period from the collection of data by Tauxe *et al.* (2013) and Quin *et al.* (2011) (Fig. 3).

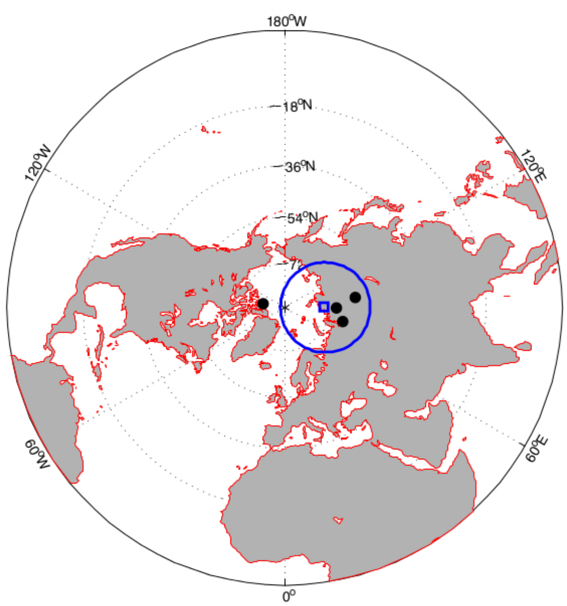

Figure 2. Map showing the locations of the VGPs of the four succesful sites (filled circles), their average (square) and its α_{95}.

Conclusions

Rock magnetic results show that the main magnetic

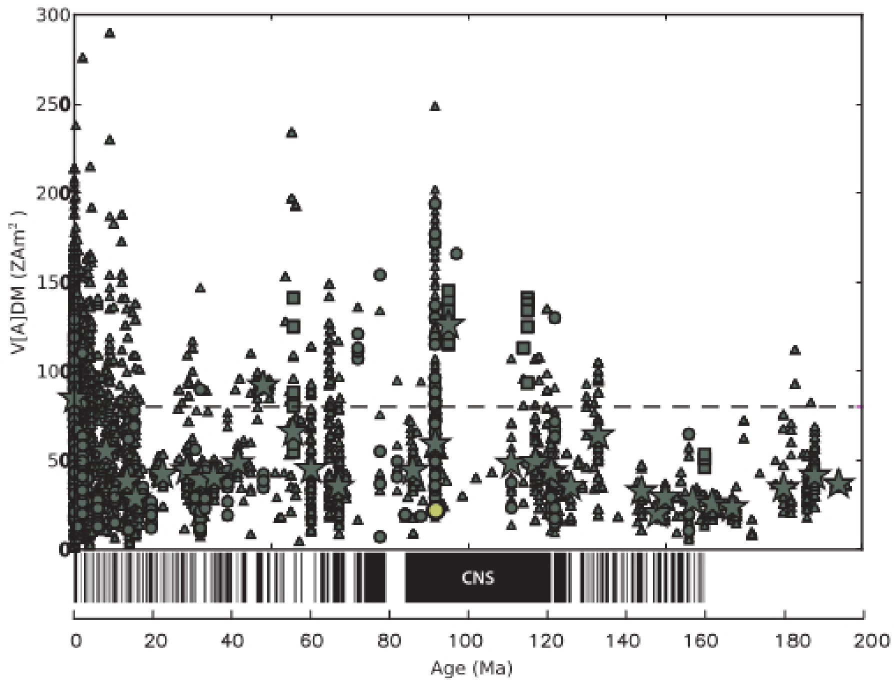

Figure 3. Summary of published data downloaded from the MagIc database. The dots are the data of basaltic glass submarines. Squares are the results of single crystal. The triangles are all other data and lighter triangles meet the criteria for special consistency. Dashed line is present the field. Data from this study are shown as large circle (figure after Tauxe *et al*., 2013).

carrier is (titano) magnetite and in general reversible thermomagnetic curves. These are good requirements for directional and intensity determinations. Nevertheless, the broad grain size range (from single to multidomain) gives rise to multicomponent demagnetization diagrams. The determined VGP agrees in its latitude more with the latitude of North America than the one of South America. This might be due to its close location to North America and needs to be further investigated. The determination of intensities with the Thellier-Coe protocol was most probably hampered by the multidomain contribution within the samples. Nevertheless, the multispecimen protocol provides successful results, probably because its smaller dependence of domain state compared to the Thellier-Coe protocol. Values of VDM support rather low field strength around 90 Ma.

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