PALEOMAGNETISM AND THE KOLYMA STRUCTURAL LOOP

David. B. Stone and Stephen G. Crumley, Geophysical Institute, University of Alaska, Fairbanks, Alaska, 99775, USA
Leonid M. Parfenov, Yakutsk Science Center, Yakutsk, Sakha Republic, Russia

ABSTRACT

The Kolyma Structural Loop (KSL) is a prominent geological feature of the eastern Sakha Republic (Yakutia). It is located between the crystaline basement rocks of the Omolon and associated terranes (the Omolon composite terrane) and the Verkhoyansk fold-and-thrust belt. The bulk of the new paleomagnetic data reported here from the KSL show evidence of a major remagnetization event. The steepness of the remagnetizing field requires the paleomagnetic pole to be close to the sampling localities at the time of remagnetization. The most recent apparent polar wander paths for the Siberian Platform show nearby poles between latest Jurassic and mid-Cretaceous time. One paleomagnetic data set from the easternmost edge of the KSL shows relatively low paleolatitudes for Jurassic aged sediments, but these paleomagnetic data come from a single locality and thus are poorly constrained. The overall paleomagnetic data set allows several models for the origin of the observed magnetization and remagnetization. Remagnetization probably was due to the migration of chemically active fluids during the compressional regime that formed the fold-and-thrust belt.

INTRODUCTION

The Kolyma Structural Loop (KSL), as defined by Zonenshain et al. (1990), is a large, complex geological structure with a horseshoe shape that is clearly outlined by the distribution of mapped rock units (Fig.1). The loop is, in fact, made up of many terranes, including fragments of Paleozoic continental shelf rocks, ophiolites with poorly constrained ages, and rocks representing a Jurassic island arc known as the Uyandina-Yasachnaya arc and belts of intrusive rocks of Cretaceous age. This whole complex is now called the Omulevka composite terrane (e.g., Parfenov, this volume), but for the purpose of this study we will continue with the more general term, the Kolyma Structural Loop. Deep-water sedimentary rocks found on either side of the KSL are thought to be the remnants of the fore- and back-arc basins associated with the Uyandina-Yasachnaya arc.

On the western side of the loop is the Kular-Nera slate belt, which is interpreted as a collapsed ocean basin. Farther west, the Kular-Nera slate belt is adjacent to, but separated from, the Verkhoyansk fold-and-thrust belt by the Adycha-Taryn fault system. The Verkhoyansk fold-and-thrust belt represents a collapsed passive margin sequence that has been thrust over the

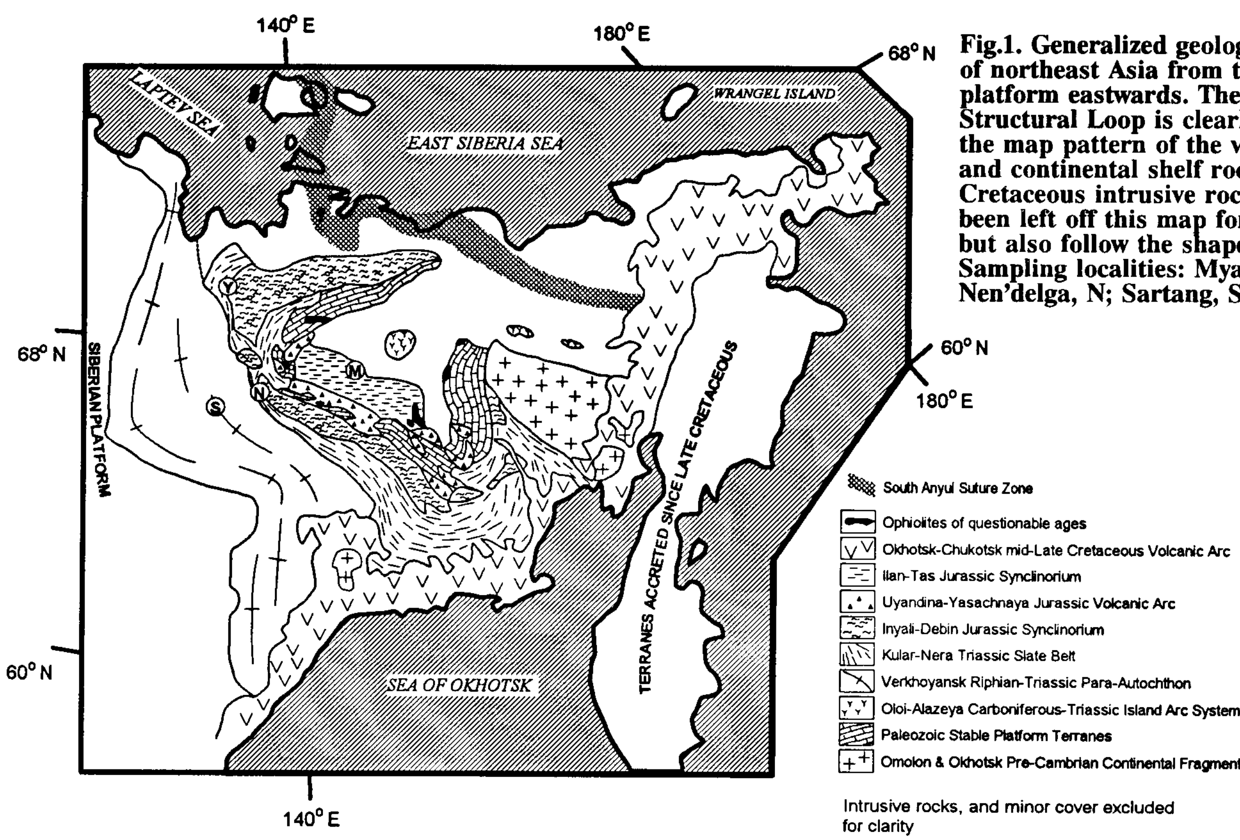

Fig.1. Generalized geological map of northeast Asia from the Siberian platform eastwards. The Kolyma Structural Loop is clearly seen in the map pattern of the various arc and continental shelf rocks. The Cretaceous intrusive rocks have been left off this map for clarity, but also follow the shape of the loop. Sampling localities: Myatis, M; Nen'delga, N; Sartang, S; Yana, Y.

edge of the Siberian platform, presumably as a result of colliding with the KSL and associated terranes. The youngest deformation associated with this collision is of latest Cretaceous age.

The KSL also forms the western boundary of the Omolon and associated terranes, known as the Omolon composite terrane (e.g., Parfenov et al., 1993; Parfenov, this volume). The center of the Omolon composite terrane is made up of Precambrian crystalline rocks, the Omolon terrane itself, and is more or less surrounded by rocks representing a Paleozoic and older continental shelf environment. It is not known whether these terranes are directly related to the apparently cratonic core of the massif. It should be noted that occcasionaly the terranes of the KSL and the Omolon composite terrane are combined as the Kolyma block, micro-continent or massif (see for example McElhinny, 1973; Churkin and Trexler, 1981; Irving, 1983).

To the north of the KSL and the Omolon composite terrane is the poorly defined South Anuyi suture zone. This suture zone is the hypothesized southern boundary of the Chukotka-Alaska terrane that includes Arctic Alaska (the Brooks Range and the Arctic slope region) and at least eastern Chukotka. The South Anuyi suture zone is traced westward to the northern arm of the KSL on the basis of magnetic anomalies, but the relationship between the KSL and the suture zone is not clear.

PALEOMAGNETIC STUDIES

Russian Data for Eastern Siberia

In general terms, the available Russian paleomagnetic data (Neustroev et al., 1993) can be interpreted as representing a collision of the Omolon composite terrane with the Uyandina-Yasachnaya arc and the Siberian platform in Jurassic time. This is consistent with the time of formation of the Verkhoyansk fold-and-thrust belt and the later intrusion of the main belt of postcollisional Cretaceous plutons. The paleolatitude data presented for the KSL (Omulevka composite terrane) by Neustroev et al. (1993) gives similar paleolatitudes to those obtained for the Siberian platform, but the degree of possible overprinting is not clear.

New Data for the KSL

Most of the paleomagnetic sampling was concentrated in deep-water sediments of Triassic and Jurassic age in the Inyali-Debin synclinorium, the Kular Nera slate belt, and in the Verkhoyansk fold-and-thrust belt (Fig.1). These localities lie between the Uyandina-Yasachnaya arc and the Siberian platform. The results from these localities are shown in Fig.2 and Table 1. Two other localities were sampled in Upper Jurassic turbidites from inside the loop of the KSL in the Ilin-Tas anticlinorium (Myatis river), on the eastern side of the Uyandina-Yasachnaya arc (Table 2). Ages of all localities are known to at least stage level based on fossils.

Nen'delga River

Localites 1-6 were near the Nen'delga river. Locality 1 consists of Jurassic aged turbidites of the Inyaly-Debin synclinorium. Fig.3 shows typical demagnetization behaviour for a sample from this locality. The remaining localites are in the upper Triassic deep water sediments of the Kular-Nera slate belt.

Sartang River

All of the passive margin turbidites sampled in this region (localities 7, 8, 9) are of uppermost Triassic and lowermost Jurassic age from within the Verkhoyansk fold-and-thrust belt. Locality 7 is thought to have undergone minor slumping, based on the relative bedding attitudes, and has thus been excluded from the overall mean.

Yana River

Locality 13 is located within the Triassic rocks of the Kular-Nera slate belt. It is overprinted, but discordant with respect to the other localities. The reason for this is not known, but local slumping is suspected. Localities 14 and 15 are located within the Poluusnyy Jurassic turbidite deposits (the northern equivalent of the Inyaly-Debin synclinorium).

Myatis River

These Upper Jurassic aged rocks are thought to represent sediments deposited in an oceanic environment adjacent to the Uyandina-Yaschnaya arc. The time available for field work in the Myatis river area was limited, and only two localities were found to be suitable for paleomagnetic work. The measurements demonstrated a positive fold test and contained field directions of both magnetic polarities (Table 2 and Fig.4). The reversal test is not compelling, because of the small number of samples involved, though the normal and reversed polarities are antipodal within the error limits. These data indicate a relatively low paleolatitude, but with significant error limits.

Locality Means

The localities west of the KSL give magnetization directions that group well (Table 1 and Fig.2) and include a vertical magnetization within the circle of 95-percent confidence. The equivalent Virtual Geomangetic Poles (VGP's) are displaced to the west of the sampling sites, that is, away from the Apparent Polar Wander (APW) paths. However, the remagnetization pole and the APW path poles overlap

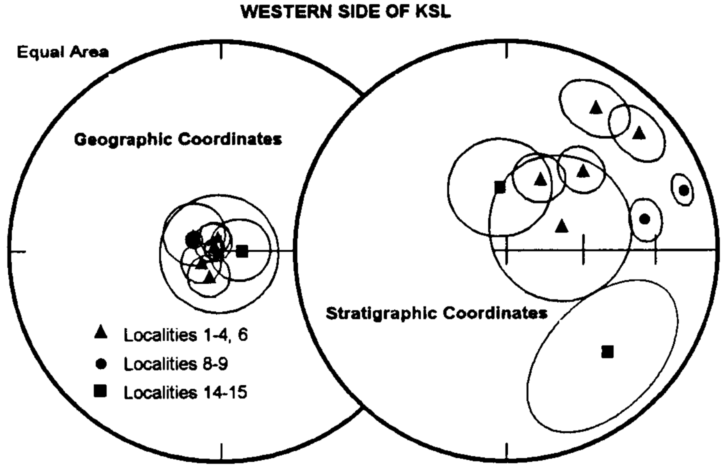

Fig.2. Equal area stereographic plots of mean paleomagnetic directions and alpha95 circles of confidence for all sites west of the KSL, excluding the slumped localities 7 and 13.

Table 1. Summary of paleomagnetic results for localities 1-15.[a]

				Geographic				*Stratigraphic*			
Locality	*Lat*	*Long*	*N*	*Dec*	*Inc*	*k*	*α95*	*Dec*	*Inc*	*k*	*α95*
1	*66.37*	*137.47*	*37*	*316.0*	*85.4*	*11.1*	*7.4*	*23.8*	*58.8*	*6.7*	*9.8*
2	*66.32*	*137.46*	*27*	*205.7*	*79.1*	*12.6*	*8.2*	*67.3*	*66.9*	*2.0*	*28.3*
3	*66.30*	*137.45*	*25*	*239.1*	*80.8*	*15.3*	*7.6*	*42.6*	*46.4*	*11.3*	*9.0*
4	*66.26*	*137.25*	*15*	*331.0*	*81.7*	*17.4*	*9.4*	*46.5*	*17.4*	*4.6*	*20.0*
6	*66.24*	*137.25*	*26*	*284.9*	*77.5*	*4.6*	*14.9*	*38.3*	*34.0*	*2.2*	*26.1*
*7**	*66.01*	*132.63*	*17*	*140.5*	*69.0*	*8.1*	*13.4*	*101.4*	*13.4*	*7.7*	*13.8*
8	*66.01*	*132.57*	*20*	*292.1*	*78.9*	*96.0*	*3.3*	*71.2*	*11.7*	*43.7*	*5.0*
9	*66.04*	*132.33*	*23*	*282.9*	*87.7*	*62.5*	*3.9*	*78.0*	*32.1*	*17.9*	*7.4*
*13**	*70.55*	*134.90*	*12*	*295.2*	*38.2*	*6.0*	*19.4*	*175.9*	*68.9*	*5.5*	*20.5*
14	*70.10*	*135.30*	*9*	*223.7*	*87.9*	*5.7*	*23.6*	*135.5*	*31.2*	*1.1*	*28.4*
15	*69.13*	*135.52*	*13*	*90.0*	*83.0*	*12.3*	*12.3*	*353.4*	*64.7*	*5.2*	*20.1*
Overall Mean			*9*	*273.7*	*85.7*	*56.9*	*4.9*	*58.9*	*46.1*	*3.0*	*23.0*
Mean of Geographic VGP's			*9*	*Long.= 115*		*Lat. = 66*			*k = 15.2*	*α95 = 9.5*	

[a]Locality number; latitude and longitude of the locality; N=the number of time units (beds) per locality= number of measurements in the mean; Declination and Inclination and the Fisher parameters kappa and alpha95 for Geographic and Stratigraphic coordinate systems. Means of directions and VGP's exclude (*) localities 7 and 13.

Table 2. Summary of paleomagnetic results for the Myatis River.[a]

Myatis River Locality				*Geographic*				*Stratigraphic*			
Site	*Lat*	*Long*	*N*	*Dec*	*Inc*	*k*	*α95*	*Dec*	*Inc*	*k*	*α95*
A	*66.83*	*145.27*	*4*	*246.0*	*12.0*	*7.9*	*35.0*	*252.0*	*58.8*	*8.2*	*34.0*
B	*66.83*	*145.27*	*5*	*33.0*	*-8.1*	*5.2*	*37.1*	*35.2*	*44.3*	*28.9*	*14.5*
A+B	*66.83*	*145.27*	*9*	*153.5*	*12.7*	*0.6*	*110.5*	*52.0*	*43.0*	*10.0*	*17.0*

[a]As for Table 1; A reversed and B normal localities. A has been inverted to obtain the mean.

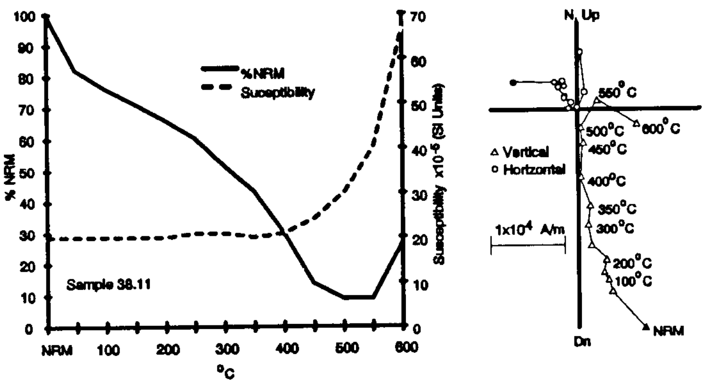

Fig.3. Typical sample behaviour during thermal demagnetization for a sample from locality 1. Left, remanence intensity and magnetic susceptibility versus temperature. Right, orthogonal (Zidjerfeld) plot of remanence vectors. Note the increased intensity and suceptibility after about 500 °C, indicating thermally induced chemical changes.

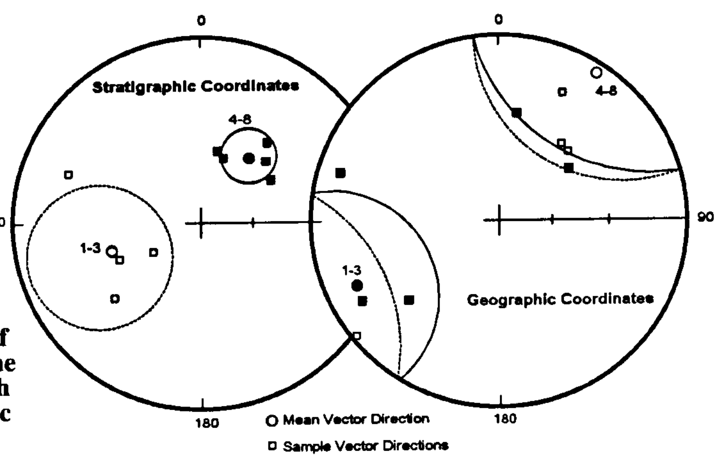

Fig.4. Stereographic projection of paleomagnetic directions from the Myatis River area plotted in both the Geographic and Stratigraphic reference frames.

within their error limits for selected times, as discussed below.

APW Paths for the Siberian Platform

The paleomagnetic data sets described for the KSL region are compared with two sets of reference poles for the Siberian Platform, displayed as APW paths. One, from Khramov (1991), is based on Russian data from the Siberian Platform combined with data from immediately adjacent regions such as the Carpathian Mountains and the Russian Platform for Mesozoic and Cenozoic time (Fig.5). The other, from Besse and Courtillot (1991), uses global reconstructions to construct an APW path for the eastern Siberian platform from published paleomagnetic for Europe, North China, and elsewhere. There are significant differences between these two APW paths, the most dramatic being for mid-Cretaceous time, a critical time with respect to possible remagnetization events in the KSL region (Fig.5).

Timing of Overprint

As demonstrated by fold tests (Table 1), all of the localities from the western side of the KSL show a complete postfolding magnetic overprint. The overprinting magnetization is consistently of normal polarity and nearly vertical at all but two localities (7 and 13), regardless of the attitudes of the bedding. This is true of both coherent packages of tilted but undeformed sediments and immediately adjacent disrupted and highly deformed packages (Fig.6). The close similarity of directions indicates no large-scale postremagnetization disruption or tilting. The very steep magnetic directions indicate that at the time of remagnetization, the sites must have been very close to the paleomagnetic pole. Using the APW path of Khramov (1991), the poles for the Siberian platform would give the steepest magnetizations at the sampling sites (assuming no relative motion between the sampling localities and the Siberian Platform) from approximately 190 to 160 m.y., and again from 110 to 90 m.y. For the key period from 150 to 120 m.y., the pole is significantly displaced to the east of the sampling localities. In direct contrast, the APW paths of Besse and Courtillot (1991) give paleomagnetic poles for the Siberian Platform that are close to the sampling localities for latest Jurassic through earliest Cretaceous time (approximately 150 to 120 m.y.) and are much more distant for mid-Cretaceous time.

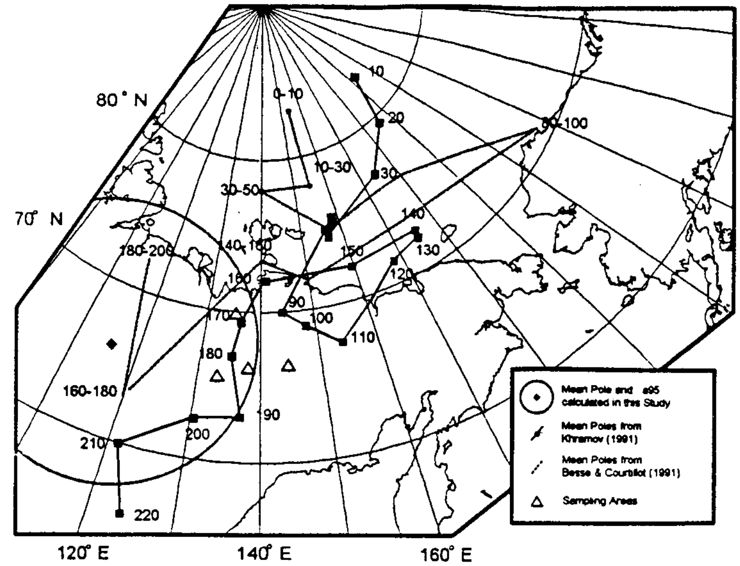

Fig.5. Composite Apparent Polar Wander (APW) paths for the eastern Siberian platform. From Khramov (1991) solid, and from Besse and Courtillot (1991) dashed. Note the major discepancy for mid-Cretaceous time. The diamond plus circle of confidence (alpha95) is the mean of the remagnetization poles reported here.

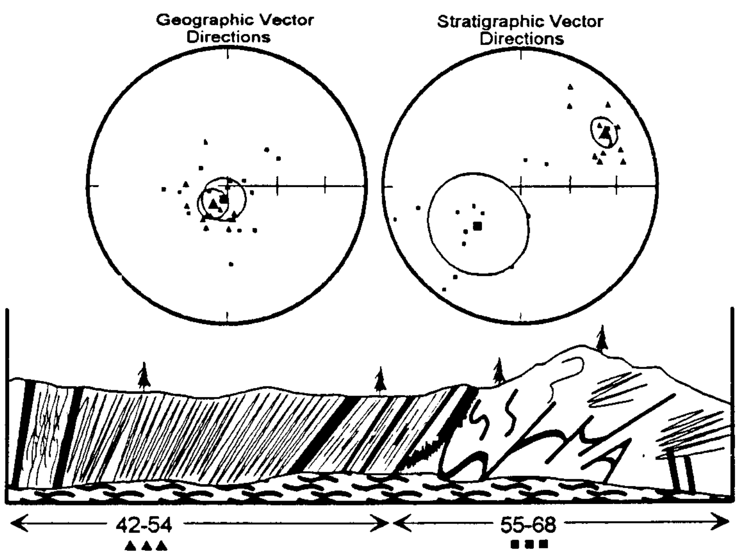

Fig.6. Paleomagnetic vector directions from Locality 2. The section sampled consisted of a coherent package of sediments adjacent to a disrupted and faulted section. As can be seen from the stereographic representation of the vector directions, the remagnetization direction pays no heed to the bedding attitudes. Squares represent vectors from the disrupted section and triangles the coherent package. Table 1 and Fig.3 show both sections combined as a locality mean.

Possible Mechanisms for Overprinting

A possible model for the origin of the observed magnetic overprint involves chemical remagnetization induced by fluid migrations. The migration of fluids is thought to be responsible for the well-known remagnetizations seen in the Appalachian Mountains of eastern North America (McCabe and Elmore, 1989) and is thought to be responsible for the pervasive (Cretaceous?) remagnetization seen in the Brooks Range of Alaska (Stone, 1989). In both of these cases, the simplistic model involves chemical changes induced by a migration of fluids driven by the compressional forces associated with the formation of a fold-and-thrust belt, the so-called "squeegee effect" (Oliver, 1986).

In the case of the Verkhoyansk fold-and-thrust belt and the westernmost outboard parts of the KSL, the consistent near-vertical remagnetization indicates that it postdates the main phase of collisional deformation, which is thought to have been completed in this area by mid- to Late Cretaceous time.

An alternate hypothesis is that the overall remagnetization was caused by the intrusion of the early to mid-Cretaceous plutons. Though the data set is not extensive, we see no relationship between the overprint and distance from the plutons that might be expected for such a scenario.

The different paleolatitudes seen in the Myatis river locality (east of the KSL) may be due to a less-direct involvement in the collisional events. A possible scenario may involve a partial remagnetization that did not completely erase the original reversal stratigraphy, followed by a later (Miocene?) local deformation that was not accompanied by a remagnetization event. This sequence of events would allow the individual sites to pass a reversal test, albeit poorly, and to pass a local fold test.

CONCLUSIONS

Our data from the western side of the KSL show that there has been pervasive magnetic overprinting of all the rocks we have studied, and that the overprinted directions are near vertical and internally consistent from one locality to another. The near-vertical paleomagnetic fields imply that a remagnetizing event occurred in latest Jurassic or mid-Cretaceous time based on the "closest approach" of the paleomagnetic poles used by Khramov (1991), or latest Jurassic to earliest Cretaceous time based on the paleomagnetic poles of Besse and Courtillot (1991). The consistency of the magnetic directions indicates that there has not been any large-scale deformation since the time of remagnetization. In contrast, the magnetization data from the inboard or eastern side of the KSL show evidence that a component of primary magnetization may have been recorded, which at face value indicates an anomalously low paleolatitude; however, the data set is sparse.

ACKNOWLEDGMENTS

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