

STRATIGRAPHY, DEPOSITIONAL SYSTEMS, AND AGE OF THE TERTIARY WHITE MOUNTAIN BASIN, DENALI FAULT SYSTEM, SOUTHWESTERN ALASKA¹

Kenneth D. Ridgway,² Jeffrey M. Trop,^{2,3} and Arthur R. Sweet⁴

ABSTRACT

The White Mountain strike-slip sedimentary basin is located adjacent to the Farewell segment of the Denali fault system in southwestern Alaska. A detailed stratigraphic section from the basin documents three main lithofacies. The lithofacies, in order of abundance, include (1) granule and pebble conglomerate; (2) massive and trough cross-stratified sandstone; and (3) mudstone. The conglomerates and sandstones contain evidence of stream-flow processes such as clast support, imbrication, crude upward-fining trends, trough cross-stratification, and unimodal paleocurrent indicators. Paleocurrent data indicate that the exposed strata of the White Mountain basin were deposited predominantly by west-flowing fluvial systems. Palynological analyses indicate that deposition in the White Mountain basin occurred during the late Oligocene and possibly into the earliest Miocene. We interpret the White Mountain basin to be time-correlative to other Oligocene strike-slip basins along the eastern and central parts of the Denali fault system such as the McGrath, Talkeetna, Burwash, and Bates Lake basins. Our correlation suggests that the Oligocene was an important time for strike-slip displacement and basin development along much of the ~2,000 km length of the fault system.

INTRODUCTION

The Denali fault system is one of the major fault systems of the northern Cordillera, extending more than 2,000 km from British Columbia to southwestern Alaska (fig. 1; Grantz, 1966; Lanphere, 1978; Dodds, 1995). Although previous studies have demonstrated that strike-slip displacement along the fault system is probably post-Early Cretaceous (Dodds, 1995), a more precise age of displacement is lacking. The amount of offset along the Denali fault system is also controversial, with estimates ranging from 0 to 450 km (see Lowey, 1998, for review). One potential data set that has been underutilized in analyzing the history of the Denali fault system is the Mesozoic and Cenozoic sedimentary basins that outcrop adjacent to the fault system (for example, Eisbacher, 1976; Nokleberg and others, 1985; Cole and others, 1996, 1999; Ridgway and others, 1997; fig. 1). A regional stratigraphic and geochronologic database of all the basins along the fault system has the potential to better define timing of displacement, and to determine if individual basins have been offset by the fault and can serve as markers to calculate fault displacement. This paper presents the first detailed stratigraphic, sedimentologic, and geochronologic data from sedimentary strata that crop out for over 15 km along the Farewell segment of the Denali fault system in southwestern Alaska. These strata are informally named the White Mountain basin (figs. 1, 2).

One catalyst for this study was to test a hypothesis that strata of the White Mountain basin, exposed on the

south side of the Denali fault system in southwestern Alaska, are offset equivalents to strata of the lower Cantwell Formation (Late Cretaceous) in the Cantwell basin, exposed on the north side of the Denali fault in the central Alaska Range (fig. 1). Sainsbury (1965) was the first to tentatively interpret the White Mountain basin deposits as time-correlative to the lower Cantwell Formation. His correlation, however, was based solely on lithologic similarities. Our study uses palynological analysis to determine if the White Mountain basin deposits are time-correlative with the lower Cantwell Formation. A recent palynological analysis of the lower Cantwell Formation has shown it to be Late Cretaceous (Ridgway and others, 1997) but a similar analysis has not been reported from strata of the White Mountain basin. Our study also presents a measured stratigraphic section from the White Mountain basin for comparison with the stratigraphy of the Cantwell basin (Trop, 1996; Ridgway and others, 1997). Stratigraphic data were collected to determine if the two basins had similar depositional histories and were possibly offset-equivalents. If the basins are offset-equivalents, about 350 km of dextral displacement would be required along the western part of the Denali fault system, a value similar to estimates of offset along the eastern part of the fault system (Eisbacher, 1976; Plafker and Berg, 1994).

Another previous mapping study (Gilbert, 1981) assigned a Tertiary age to the White Mountain basin deposits because of their lithologic similarity to the

¹Geological Survey of Canada Contribution No. 1998218.

²Department of Earth and Atmospheric Sciences, Purdue University, West Lafayette, IN 47907-1397.

Email for Kenneth D. Ridgway: ridge@omni.cc.purdue.edu

³Present address: Department of Geology, Bucknell University, Lewisburg, PA 17837.

⁴Geological Survey of Canada, Calgary, Alberta T2L 2A7, Canada.

Usibelli Group (Wahrhaftig and others, 1969; Wahrhaftig, 1987). The Usibelli Group is exposed north of the central Alaska Range in the Usibelli basin (fig. 1). The Usibelli Group ranges in age from Late Eocene to Miocene, but most of the deposits are Miocene (Wahrhaftig and others, 1969; Leopold and Liu, 1994). At the type section, for example, the entire Usibelli Group (about 585 m) is Miocene (Leopold and Liu, 1994).

This paper presents new geochronologic, sedimentologic, and paleocurrent data from surface exposures of the White Mountain basin. Our analysis allows comparison of timing of deposition in the White Mountain basin to Late Cretaceous development of thrust-top basins (Cantwell basin on fig. 1; Ridgway and others, 1997), Eocene-Oligocene strike-slip basins (Burwash and Bates Lake basins; Ridgway and DeCelles, 1993a, b), and Miocene foreland basins (Usibelli Group; Ridgway and

others, 1998, 1999) of southern Alaska and northwestern Canada.

STRATIGRAPHY AND DEPOSITIONAL SYSTEMS

Our stratigraphic and sedimentologic data from the White Mountain basin are from a 440 m detailed measured stratigraphic section (fig. 3) located in the northeastern corner of the basin (fig. 2). The basal contact between deposits of the White Mountain basin and underlying rocks is not exposed, and the top of the section is eroded; therefore the original thickness of the basin fill cannot be determined. The measured section at White Mountain is dominated by three main lithofacies, which are, in order of abundance: (1) granule and pebble conglomerate; (2) massive and trough cross-stratified sandstone; and (3) mudstone.

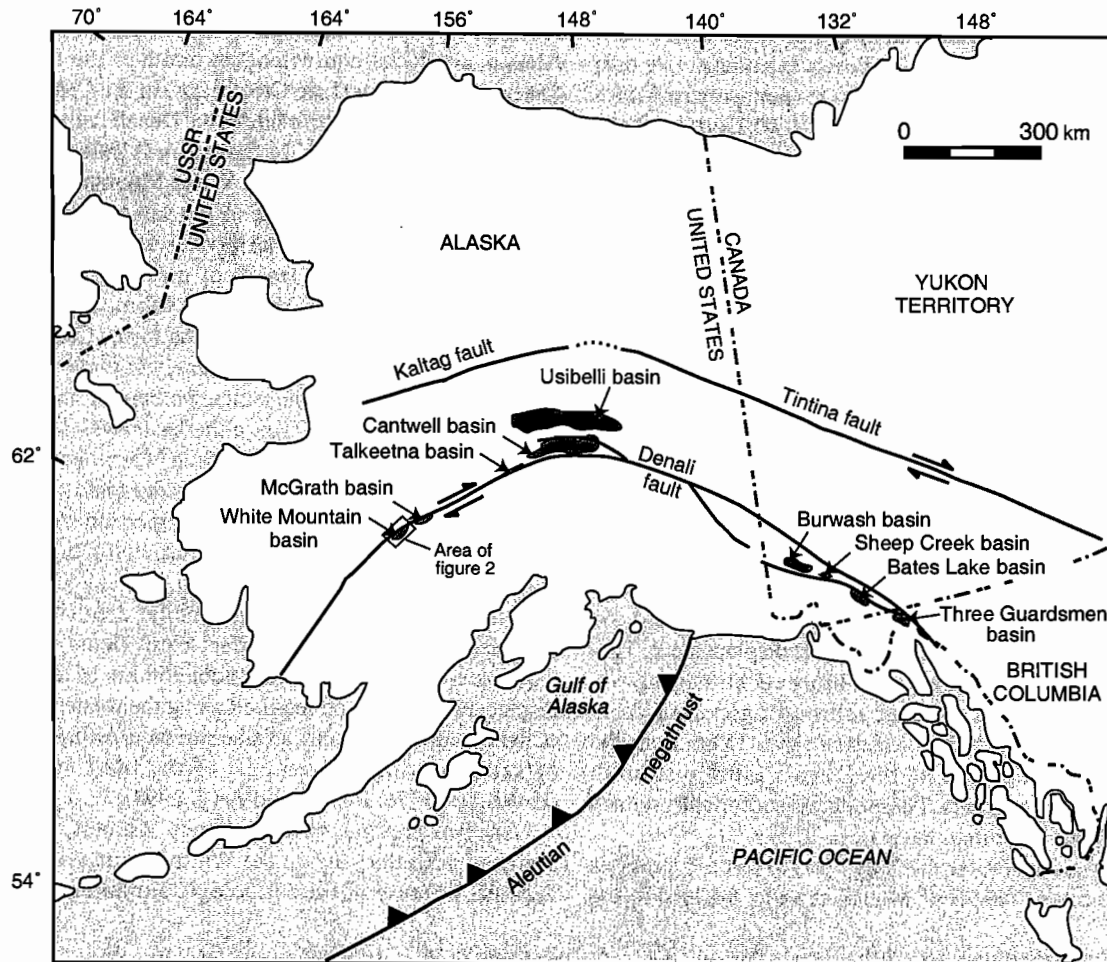


Figure 1. Map of the Denali fault system in British Columbia, Yukon Territory, and Alaska showing the location of sedimentary basins (dark gray shaded areas). The Sheep Creek and Three Guardsmen strike-slip basins are not discussed in the text, but their locations are shown.

LITHOFACIES 1 - GRANULE AND PEBBLE CONGLOMERATE

Clast-supported, granule and pebble conglomerate is the dominant lithofacies in the White Mountain basin measured section (figs. 3, 4). Conglomerates are medium- to thick-bedded, are well sorted, and contain rounded clasts (fig. 5A). Average maximum clast size in the conglomerate is 5 cm (figs. 3, 5B). Common clast types in the conglomerates are quartz, argillite, and chert (fig. 3). Lenticular sandstones (less than 50 cm thick) are commonly interbedded within the conglomerates. Where Lithofacies 1 is best exposed in our measured section (for example, 12.5 to 18 m and 34 to 40 m on fig. 3), it consists of upward-fining sequences that have a lower 1- to 4-m-thick conglomerate unit capped by a 0.5- to 1-m-thick massive sandstone. Few sedimentary structures were recognized in Lithofacies 1, but clast imbrication is present. At five different stratigraphic positions in the section, we measured 10 imbricated clasts from a single conglomerate bed to determine paleocurrent direction. The stratigraphic position of these measurements and restored paleocurrent orientations are shown on figure 3. The measurements indicate an overall westward paleoflow.

LITHOFACIES 2 - MASSIVE AND TROUGH CROSS-STRATIFIED SANDSTONE

Lithofacies 2 consists mainly of massive, coarse- to medium-grained sandstone with maximum bed thicknesses of ~6 m. Trough cross-stratification was documented in some units but other sedimentary structures are uncommon. Conglomerate lags and lenses are common in Lithofacies 2.

LITHOFACIES 3 - MUDSTONE

Lithofacies 3 consists of poorly exposed mudstone that was best studied by trenching. Most of the lithofacies consists of alternating thin beds (less than 15 cm) of siltstone and shale. Plant fragments were documented in this lithofacies. Samples for palynological analysis were collected from this lithofacies (table 1).

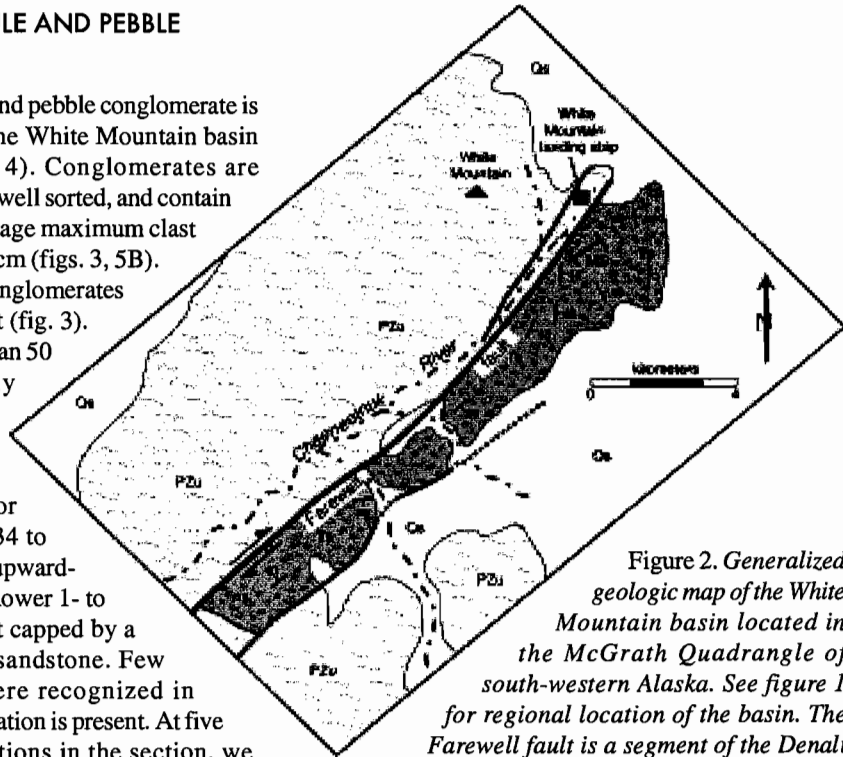


Figure 2. Generalized geologic map of the White Mountain basin located in the McGrath Quadrangle of south-western Alaska. See figure 1 for regional location of the basin. The Farewell fault is a segment of the Denali fault system. PZu = Mesozoic-Paleozoic rocks of the Farewell terrane and White Mountain sequence (Decker and others, 1994); Ts = sedimentary strata of the White Mountain basin; Qs = Quaternary deposits. MS = location of measured stratigraphic section shown on figure 3. Geology and structural data from Gilbert (1981).

Table 1. Type and abundances of pollen and miospores

Species	Percentage of Sample		
	155 m	330 m	387 m
Gymnosperm pollen			
T/C/T ^a	65.2	83.1	42.0
Bisaccate	6.5	3.1	21.0
<i>Tsuga</i>	3.3	0.8	2.1
Miospores			
<i>Laevigatosporites</i>	11.4	4.6	8.4
<i>Lycopodium</i>	0.0	0.0	0.4
<i>Cyathidites</i>	0.0	0.0	0.4
Angiosperm pollen			
<i>Alnus</i>	8.2	5.8	19.3
Betulaceae	3.3	2.3	5.5
<i>Pterocarya</i>	0.0	0.0	0.4
Tricolpate	0.0	0.0	0.4
Total Number of Taxa Counted	230	254	238

^aT/C/T = Taxodiaceae/Cupressaceae/Taxaceae

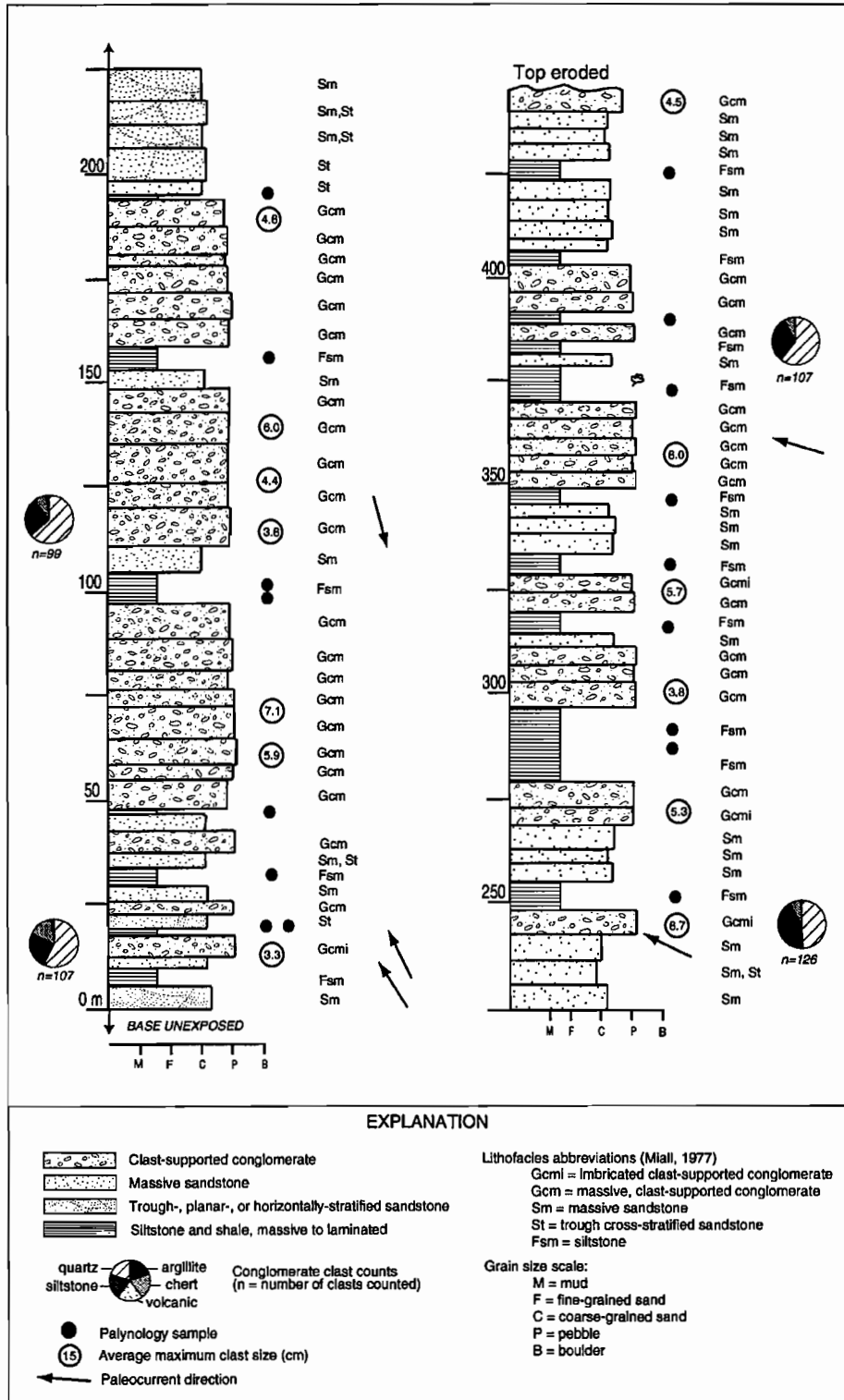


Figure 3. Measured stratigraphic section of the White Mountain basin showing lithofacies in the northeastern part of the basin. Vertical scale is in meters. Each arrow represents restored paleocurrent direction based on mean measurement of ten imbricated conglomerate clasts. See figure 2 for location of measured section.

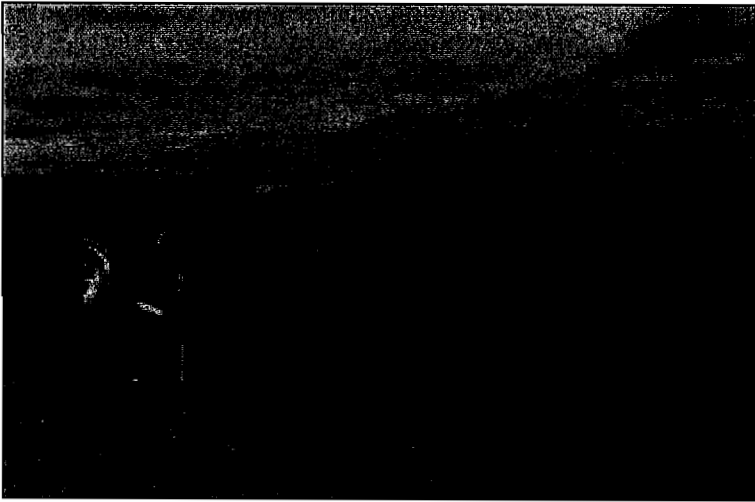


Figure 4. *Typical outcrops of the White Mountain basin. Beds are dipping about 45° southeast (to the left in the photo). Conglomerates and sandstones of Lithofacies 1 and 2 form resistant along-strike ridges. Recessive grassy layers are mudstones of Lithofacies 3. Trace of the Farewell fault is in the large valley between the outcrops and the man. Stratigraphic section shown in figure 3 was measured in this area.*

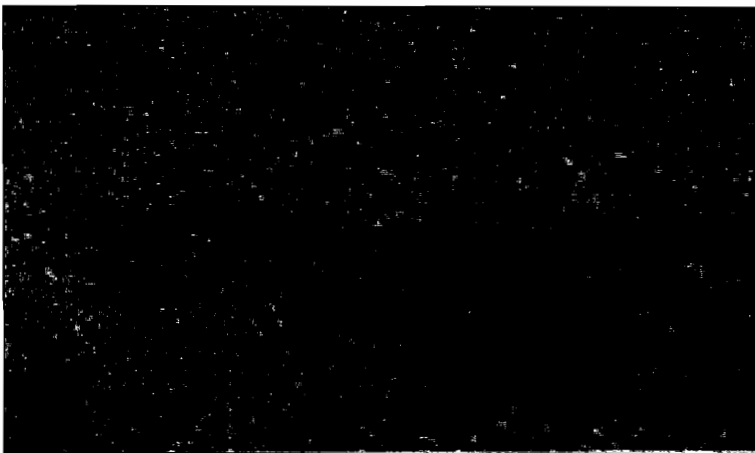


Figure 5A. *Granule and pebble conglomerate of Lithofacies 1. Lichens cover the lower right part of the outcrop. Hammer is 28 cm long.*

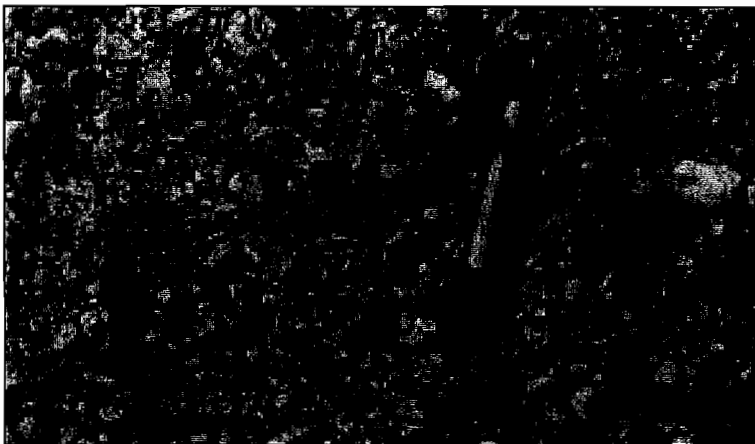


Figure 5B. *Close-up of clast-supported conglomerate of Lithofacies 1. Pen is about 14 cm long.*

DEPOSITIONAL SYSTEMS INTERPRETATION

We interpret the White Mountain basin strata as having been deposited predominantly by fluvial depositional systems. The conglomerates (Lithofacies 1) and sandstones (Lithofacies 2) contain evidence of stream-flow processes including clast support, imbrication, crude upward-fining trends, trough cross-stratification, and fairly unimodal paleocurrent indicators. Lithofacies 1 and 2 appear similar to lithofacies described for modern low-sinuosity stream systems where gravel and sand are transported as bedload and deposited on longitudinal bars and within channels (Rust, 1978; Collinson, 1986). The laterally discontinuous lenses of sandstone within conglomerates of Lithofacies 1 were probably deposited in shallow channels on bar tops and along the flanks of bars during falling-stage and low-stage flows (Miall, 1977).

The mudstones of Lithofacies 3 require low energy depositional processes with a large component of suspension fallout. Suspension fallout within the proposed fluvial deposystem probably occurred mainly in overbank areas where flood water underwent a sudden decrease in velocity or where sediment entered ponded areas within the basin. A fluvial overbank interpretation for Lithofacies 3 is consistent with the presence of plant megafossils, a lack of marine megafossils, and the absence of marine microfossils (checked for during palynological analyses).

AGE

The age of the White Mountain basin deposits has been unclear due to a lack of age data. Previous studies have interpreted the age of the White Mountain strata as Early Cretaceous (Sainsbury, 1965) or Tertiary (Gilbert, 1981) on the basis of regional lithologic correlations. To better constrain the age of the White Mountain basin, palynological analyses were conducted by one of us (ARS) on 17 mudstone samples collected from our measured stratigraphic section. Locations of samples are shown on figure 3. Table 1 shows counts from the three best preserved assemblages recovered from the stratigraphic section (155, 330, and 387 m). Similar palynoflora are present in all 17 of the samples over the entire 440 m of measured section.

Palynological analyses indicate that strata of the White Mountain basin were most likely deposited during the late Oligocene or earliest Miocene. The age interpretation is based on the following arguments. The presence of *Alnus*, *Pterocarya*, and *Tsuga*, of modern aspect, restricts the age to being within the range of Eocene to Miocene or possibly early Pliocene (table 1). The persistent absence of *Pistillipollenites* and a wide range of warm temperate taxa (*Fagus*, *Liquidambar*,

Quercus, and *Tilia*) further restricts the age to within the range of Oligocene to possibly early Pliocene. The apparent absence of *Parviprojectus* makes it unlikely that the samples are of early Oligocene age. When compared to the late early Miocene Upper Ramparts Canyon organic bed 1 in central Alaska, which is dominated by bisaccates with relatively low Taxodiaceae/Cupressaceae/Taxaceae counts (White and Ager, 1994), our data does not compare well (table 1). Deposition during the late early Miocene is, therefore, unlikely (J.M. White, written commun., 1996). The low diversity and the lack of thermophilous taxa in the White Mountain basin samples (even in the three best preserved assemblages; table 1) eliminate the warm interval within the middle Miocene (White and others, 1997). The lack of herbs (Cyperaceae, *Ambrosia*, Poaceae, other Asteraceae, Polemoniaceae) probably eliminates the late Miocene–Pleistocene (White and others, 1997).

In addition to the constraints stated above, the abundance of *Picea* and *Tsuga*, the dominance of *Alnus* in the angiosperm component, the less frequent presence of *Pterocarya*, and the possibly rare occurrence of *Juglans*, suggest that the late Oligocene or earliest Miocene is the most probable age for the assemblage—a time of relatively cool but moist climate (Wolfe, 1986; J.M. White, written commun., 1996). Similar assemblages are present in the youngest strata of the Oligocene Amphitheatre Formation, Burwash basin, Canada, but they contain *Parviprojectus* (Ridgway and others, 1995). Our preferred age interpretation for the exposed strata of the White Mountain basin, then, is late Oligocene possibly extending into the earliest Miocene.

DISCUSSION

This study shows that the deposits of the White Mountain basin along the Farewell segment of the Denali fault system in southwestern Alaska were deposited by fluvial deposystems during the late Oligocene and possibly into the earliest Miocene. The major fluvial system probably entered the basin from the east and deposited sediment as it flowed westward along the axis of the White Mountain basin. The late Oligocene or earliest Miocene fluvial system may have been part of a regional drainage system that flowed west-southwestward, possibly in part along a trough controlled by the Denali fault system. The same general fluvial system may have deposited sediment in other nonmarine strike-slip basins presently located to the northeast along the Denali fault system, including the McGrath and Talkeetna basins of Dickey (1984) (fig. 1). The McGrath basin, located about 25 km northeast of the White Mountain basin, is characterized by an overall southward paleoflow (Dickey, 1984). Dickey (1984) reports that no palynomorphs were recovered from

samples collected during his study of the McGrath basin, but that unpublished data of ARCO Alaska, Inc. identified Eocene to middle Oligocene pollen in equivalent deposits. The Talkeetna basin was mapped by Reed and Nelson (1980) along the north side of the central part of the Denali fault system (fig. 1). No palynological studies have been published on the Talkeetna basin. Dickey (1984) correlated the Talkeetna basin with the McGrath basin based on similar petrologic characteristics.

We interpret the White Mountain basin to be time-equivalent to Eocene-Oligocene strike-slip basins located along the eastern part of the Denali fault system in the Yukon Territory, Canada, on the basis of similar pollen assemblages (for example, Burwash and Bates Lake basins on fig. 1). For a detailed discussion on the palynology and structural development of strike-slip basins in the Yukon Territory, see Ridgway (1992) and Ridgway and others (1995). Our correlation disagrees with Sainsbury's (1965) correlation of the White Mountain basin with the Late Cretaceous Cantwell basin (fig. 1) and with Gilbert's (1981) correlation of the White Mountain basin with the Usibelli basin (fig. 1). Since Gilbert's (1981) map was published, detailed palynological studies have shown that most of the Usibelli Group was deposited during the middle and late Miocene (Leopold and Liu, 1994; Liu and Leopold, 1994). If the White Mountain basin is time-correlative to strike-slip basins along the eastern and central parts of the Denali fault system, it would suggest that the Oligocene was an important time for strike-slip displacement and basin development along the entire fault system.

Our analysis of the White Mountain basin is limited to one measured section, and much more research needs to be done on this basin and other strike-slip basins along the Denali fault system. Not until all the basins along this fault system are studied will a complete understanding of this ~2,000-km-long tectonic feature be possible. We hope that the data from this study will be a useful starting point for future studies of the White Mountain basin.

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