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Commentaires

COMMENT ON "AGE OF PRE-NEOGLACIAL CIRQUE MORAINES IN THE CENTRAL NORTH AMERICAN CORDILLERA", BY P. T. DAVIS AND G. OSBORN

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Several aspects of the recent paper by Davis and Osborn (1987) deserve additional comment. First, the authors have incorrectly located the radiocarbon sites of Begét (1981, 1983, 1984) at the White Chuck Cinder Cone. They begin a discussion of these sites by stating that, "we were unable to locate the charcoal locality", but nonetheless argue that some radiocarbon dates reported by Begét from Glacier Peak were collected from colluvium deposited in a low, flat area on White Chuck drift. They apparently arbitrarily assumed the charcoal locality lay in a "low flat area... bounded by slopes," but this locality bears no resemblance to the two actual charcoal sites. In contrast to the area described by Davis and Osborn, no gully exists above the actual sample locality, it is not in the overflow area of a pond, and it does not occur on the floor of a flat basin. The samples in question were not found in gullied *ground moraine and colluvium in a low flat area or depression*, as assumed by Davis and Osborn, but near the crest of a morainal ridge. I supplied them with a sketch map of the locality before they went to Glacier Peak, but the gully, pond, and other physical features they discuss in their critique lie as far as several hundred meters southwest from the actual charcoal locality. Since their discussion of radiocarbon dates is based on faulty assumptions about the location and depositional environment of samples, their discussions of the provenance of the charcoal used to determine a limiting date on the White Chuck drift are misapplied.

In addition to misidentifying the radiocarbon locality at the White Chuck Cinder Cone, Davis and Osborn neglect consideration of the implications of tephrochronologic dating of the White Chuck drift and other pre-Mazama cirque moraines in the North Cascades. Tephra layers G and B from Glacier Peak are preserved in and around many cirques in the North Cascades (Waitt *et al.*, 1982; Begét, 1984), and on the White Chuck Cinder Cone (Begét, 1981), indicating that deglaciation had largely occurred by the time of these eruptions. The White Chuck drift and other pre-Mazama cirque moraines found widely in the North Cascades are younger than these tephra layers (*i.e.*, <11,200 yrs BP). This is consistent with the radiocarbon dates from drift reported by Begét (1981; 1984) and precludes correlation of these cirque moraines found widely in the North Cascades with *ca.* 12,000 yrs BP Temple Lake drift or Triple Lakes moraines. Perhaps late Pleistocene cirque moraines in the Rocky Mountains correlate with Carne Mountain drift (Begét, 1984), which occurs in some cirques in the North Cascades and predates the Glacier Peak eruptions (Fig. 1).

Two other points deserve additional comment. First, the authors maintain that oscillations of climate and concomitant glacier advances did not occur in the early Holocene because models of orbital climatic forcing do not retrodict such climate change. This argument is flawed because it assumes that astronomic effects, which operate on a scale of 10^4-10^5 years (Berger, 1978), are solely responsible for and can be correlated with terrestrial climate changes on the scale of 10^2-10^3 years. In actuality, any short-term oscillation which has occurred in Holocene or Pleistocene climate, such as the Little Ice Age, Neoglaciation, the Younger Dryas advances, etc., is much too brief to be attributed exclusively to orbital effects (Fig. 1).

Several mechanisms have been proposed which are much more likely to have produced short term oscillations of climate, including changes in atmospheric CO_2 content (Delmas *et al.*, 1980; Neftal *et al.*, 1982;), solar variability (Sofia, 1984), volcanic eruptions (Porter, 1986; Lamb, 1970), changes in ocean mixing or current displacement (Broecker and Takahashi, 1984), or coupled ocean-atmosphere-cryosphere feedback systems (Dansgaard *et al.*, 1984; Berger and Keir, 1984).

One or more of these mechanisms may have influenced climate during the early Holocene. For instance, Neftal *et al.* (1988) report that atmospheric CO_2 levels determined from an Antarctic ice core increased from ~200 p.p.m.v. during the Pleistocene to ~280 p.p.m.v. during the Holocene. Of interest here is the fact that after atmospheric CO_2 reaches its highest levels in the Byrd ice core at ~10,000 yrs BP, a marked decrease occurred at approximately 8000-7000 yrs BP. Neftal *et al.*, (1988, p. 611) state that, "changes of up to 40 p.p.m.v. of the atmospheric concentration occurred," and "we consider the observed minimum of 245-255 p.p.m.v. ~8000 yr BP to be real." By 6500 yr BP CO_2 had again increased to high levels. The early Holocene atmospheric CO_2 depression of 40 p.p.m.v. at ~8000 yr BP is 30-40% as large

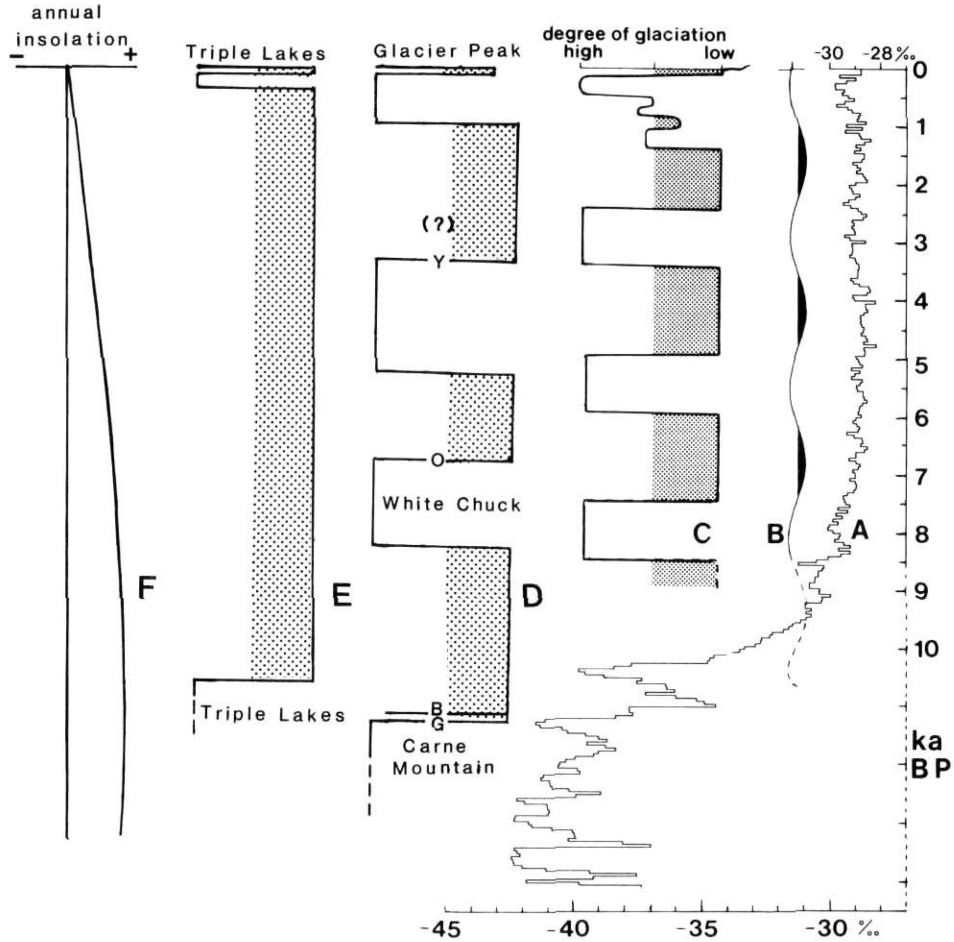

FIGURE 1. Selected proxy climatic curves for the Holocene: A) High resolution stable isotope record from the upper part of Camp Century ice core (Dansgaard *et al.*, 1984). B) Filtered and smoothed proxy climatic curve from Camp Century ice core, showing climatic oscillations with periodicity of 2550 years (Dansgaard *et al.*, 1984). C) Model of worldwide alpine glaciation, from Denton and Karlen (1973). D) Glacial chronology at Glacier Peak, Washington from Begét (1981, 1984). Limiting dates from tephra layers Y,O,G, and B, shown by labelled horizontal lines. Other horizontal lines show radiocarbon limiting dates E) Glacial moraine chronology from Triple Lakes, Colorado, from Davis and Osborn (1987). Lowermost horizontal line shows a radiocarbon limiting date. Triple Lakes moraines redefined as Santana Peak drift by Birkeland *et al.* (1987). F) Net annual solar insulation at 45°N (Berger, 1978; Davis *et al.*, 1986). Note poor agreement with glacial and isotopic proxy climate data. This figure is modified from Dansgaard *et al.*, (1984).

Courbes climatiques choisies de l'Holocène établies à partir de données indirectes: A) relevé isotopique à haute résolution en provenance de la partie supérieure du noyau de glace de Camp Century (Dansgaard et al., *1984). B) Courbe climatique épurée et adoucie, établie à partir de données indirectes, montrant des oscillations climatiques selon une périodicité de 2550 ans (Dansgaard* et al., *1984). C) Modèle des glaciations alpines mondiales de Denton et Karlen (1973). D) Chronologie glaciaire à Glacier Peak, Washington, de Begét (1981, 1984). Les lignes horizontales correspondent aux seuils chronologiques identifiés par les couches de tephra Y, O, G et B; les autres, à des seuils déterminés par datation au radiocarbone. E) Chronologie glaciaire des moraines de Triple Lakes, Colorado, de Davis et Osborn (1987). La ligne horizontale inférieure représente un seuil chronologique fixé par datation au radiocarbone. Birkeland* et al. *(1987) ont remplacé l'expression moraines de Triple Lakes par dépôts de Santana Peak. F) Insolation nette au 45°N. (Berger, 1978; Davis* et al., *1986). À noter la faible concordance avec les données glaciaires et les données isotopiques indirectes. Cette figure a été modifiée de Dansgaard* et al. *(1984).*

as the measured CO_2 decrease determined for the Pleistocene atmosphere at full glacial conditions. The early Holocene atmospheric CO_2 decrease may reflect or cause climate change, as in generally inferred for the Pleistocene CO_2 decrease.

Acidity records from the Crete ice core suggest that volcanic eruptions as large or larger than the Mt. Mazama eruption occurred at *ca.* 8048 and 8218 yr BP, possibly producing short term changes in climate (Hammer *et al.*, 1980; Porter, 1988).

Solar variability through the Holocene is suggested by ^{14}C production and $^{18}O/^{16}O$ residuals from both Greenland and Devon Island ice cores (Fisher, 1982). Dansgaard *et al.* (1984) also found evidence for periodic Holocene climatic oscillations (see below).

Davis and Osborn rely almost exclusively on pollen studies in their discussion of paleoecologic and paleoclimatic data. Their discussion mixes vegetation records from both high and low elevation bogs and lakes, even though it is likely that vegetation at the diverse sites responded in different ways to short term climatic events. Contrasts in climatic histories from adjacent high and low elevation pollen records in the western United States are well documented (Davis *et al.*, 1986). While the pollen records cited by Davis and Osborn all reflect Pleistocene/Holocene climate change, only a few show evidence of early Holocene climatic fluctuations. However, several which do not are from low elevation sites, such as the Hoh Rain Forest, and do not reflect any Holocene climatic fluctuations, and thus constitute poor tests of Holocene climate change.

Davis and Osborn do not consider proxy climatic data sets other than pollen curves, including some which may be especially sensitive to glacier fluctuations. Pertinent examples are records of organic carbon contents in lake cores from glaciated basins. Leonard (1986) suggested that the organic carbon record from lake cores taken from glaciated basins of the Canadian Cordillera may record a climatic oscillation and glacier advance in the early Holocene. In Wyoming, the organic carbon records from Rapid Lake, Miller Lake, and Temple Lake all show decreases in organic carbon during portions of the early Holocene which might reflect a climatic oscillation and an early Holocene glacial advance (Zielínski and Davis, 1987, Figs. 3, 4, 5). In Colorado, lake records from the San Juan Mountains also may reflect an early Holocene climatic oscillation (Andrews *et al.*, 1975).

Proxy climate records derived from stable isotope studies have proven to be very powerful techniques for deciphering the history of climatic oscillations. Perhaps this tool, which has been so important in resolving the picture of Pleistocene climate change, should be considered by students of Holocene climate. The high resolution stable isotope curve from the upper part of the Camp Century ice core by Dansgaard *et al.* (1984) is the most detailed stable isotope record available for the Holocene at this time. This curve, derived from analyses of annual snow layers, is estimated to be dated to better than ±2% through most of the Holocene, and constitutes an extremely detailed and well-dated proxy climatic record of conditions in the North Atlantic and Northern Hemisphere. Good agreement with the stable isotope record from the upper parts of the Dye 3 ice core indicate these proxy records of Holocene climate have regional significance.

Dansgaard *et al.* (1984) report that climate during the Holocene has been characterized by periodic oscillations during which conditions became more favorable for glacier growth. These periods occurred from *ca.* 1500-100 yrs BP, 3400-2300 yrs BP, 5700-4700 yrs BP, and from 8500-7500 yrs BP, *i.e.* much too rapidly to be attributed to Milankovitch effects (Fig. 1).

The identification of periodic climatic oscillations through the Holocene by Dansgaard *et al.* (1984) agrees with the findings of Fisher (1982) and supports Denton and Karlen (1973), who suggested that alpine glaciers expanded at about these times. The stable isotope curve also supports the hypothesis of Begét (1983, 1984) that climate varied and alpine glaciers fluctuated in size throughout the Holocene (Fig. 1). Deposits of successively older Holocene ice advances, because of fluvial erosion and/or burial by subsequent ice advances, are unlikely to be found in every cirque. Early Holocene moraines are apparently absent from the localities studied by Davis and Osborn. However, this does not preclude the possibility of climatic fluctuations in the early Holocene, or the existence of early Holocene moraines in other areas.

To summarize, (1) it is unrealistic to attempt to correlate Holocene climatic oscillations lasting 10^2-10^3 years (and concomitant glacial advances) with orbitally controlled insolation changes occurring over 10^4-10^5 years, as argued by Davis and Osborn. Holocene alpine moraines probably record climatic oscillations produced by short-term effects. (2) Some continuous proxy climatic data, including several organic carbon records from alpine lakes in the Rockies, and the high resolution geochemical studies of ice cores by Netfal *et al.* (1988), Fisher (1982), and Dansgaard *et al.* (1984), indicate that several significant climatic oscillations have occurred through the Holocene, including intervals of time favorable for glacier growth between 7500-8500 yrs BP. (3) Davis and Osborn (1987) incorrectly located the radiocarbon sample sites of Begét at Glacier Peak, obviating their discussion of sample provenance. Both radiocarbon dates and tephrochronology indicate that some pre-Neoglacial cirque moraines in the North Cascades are younger than late Pleistocene cirque moraines in the Rocky Mountains.

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