RECORD OF THE SOUTHWEST MONSOON FROM GULF OF MEXICO SEDIMENT CORES

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ABSTRACT

Summer monsoonal rains are an important source of moisture to portions of southwestern United States and northern Mexico. Changes in the amount and the seasonal distribution of precipitation in this semi-arid region influence overall water supply and severity of wildfires. Historical records demonstrate that precipitation in the southwestern US is quite variable, but the long-term (millennial-scale) variability of the monsoon system is not yet known. Studies based on tree-rings provide highly resolved records of past conditions but determining seasonality of precipitation is challenging. In addition, these records usually represent short intervals of the Holocene and often reflect local conditions. Studies of pollen in lake sediments, lake shoreline deposits and vegetation in packrat middens are also available, but these records are often discontinuous, many are difficult to date, and they are sometimes contradictory.

Variations in the relative abundance of the planktic foraminifer *Globigerinoides sacculifer* in marine sediments from the Pigmy Basin in the Gulf of Mexico (GOM) closely match the tree-ring record from El Malpais National Monument on the southern periphery of the Colorado Plateau in the west-central New Mexico. The tree-ring record from El Malpais is sensitive to variations in the southwestern monsoon because precipitation in New Mexico occurs predominantly in the mid-summer to fall (June to October). The Pigmy Basin record confirms a severe multi-century drought centered at ~1600 calendar years BP as well as several multidecadal droughts that are present in the El Malpais record. The similarity of the Pigmy Basin and El Malpais records suggests that variations in *G. sacculifer* abundance in marine sediments from the Gulf of Mexico can be used as a proxy for constructing a highly resolved, well-dated, and continuous history of the southwest monsoon for the entire Holocene.

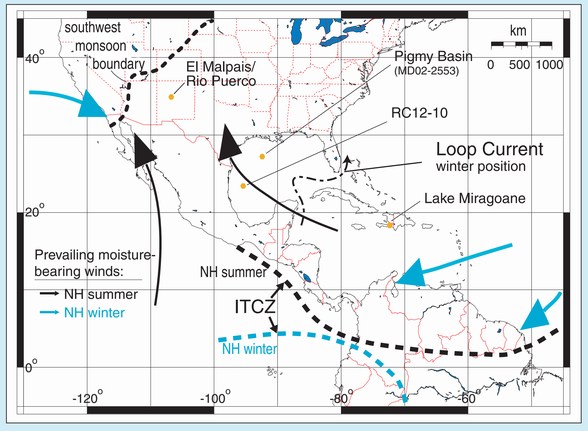

Fig. 1 Location of Lake Miragoane in Haiti, core RC 12-10 in western Gulf of Mexico, core MD02-2553 from the Pigmy Basin on the Louisiana slope, Rio Puerco Basin and El Malpais National Monument. Large arrows show prevailing wind direction during Northern Hemisphere winter and summer seasons. Small dash-dotted arrow shows generalized position of Loop Current during Northern Hemisphere winter. Dashed line shows position of Intertropical Convergence Zone (ITCZ) in Northern Hemisphere winter and summer seasons. Dotted line labeled southwest monsoon boundary marks northern limit of regions where more than half annual precipitation occurs during the warm season. Modified from Metcalfe *et al*., 2000; Peterson, 1994; and Poore *et al*., 2003.

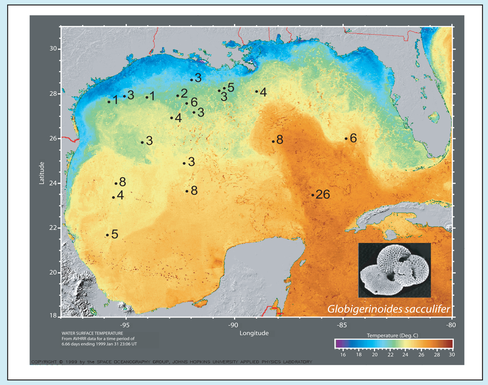

Fig. 2 Relative abundance of the planktic foraminifer *G. sacculifer* in modern or near-modern core top assemblages (modified from Poore *et al*., 2003). Small filled circles are core top locations and numbers next to the filled circles are the % *G. sacculifer* of the planktic foraminifer assemblage (> 150 um). Sea surface temperature for December 1999 is illustrated. *G. sacculifer* is common in Caribbean core top assemblages and is associated with the Loop Current in the Gulf of Mexico.
Note that *G. sacculifer* is only abundant in core top sample from the southeastern GOM where the warm Loop Current is present all year. The abundance of *G. sacculifer* in the remaining GOM core top assemblages declines towards the west and north where the Loop Current influence is seasonal. The abundance of *G. sacculifer* is lowest near the Texas and Louisiana coast where the Loop Current influence is weakest all year.

Changes in the average position of the ITCZ modulate the influence of the Loop Current in the western and northern GOM. Northward movement of the average position of the ITCZ enhances "summer circulation" which increases the influence of Loop Current and results in increased abundances of *G. sacculifer* in sediments in the western and northern GOM. Southward movement of the average position of the ITCZ has the opposite effect. We use the abundance of *G. sacculifer* in core samples as a proxy of Loop Current influence in the GOM.

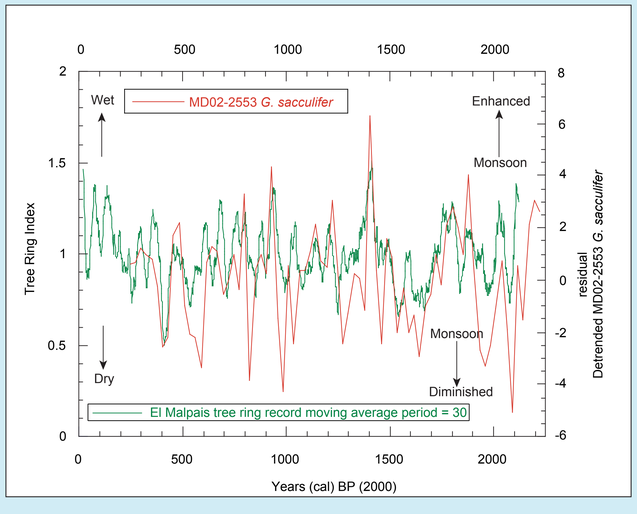

Fig.3 Comparison of time-series of standard tree-ring width index developed from living trees and subfossil wood at El Malpais National Monument in west-central New Mexico and relative abundance of *G. sacculifer* in core MD02-2553 from the Pigmy Basin in the northern Gulf of Mexico (see Fig. 1). The MD02-2553 record has been detrended to remove low-frequency variability. Time scale is in calendar years before present (BP; before 2000). Each record is plotted against its own independent chronology. Development of the El Malpais chronology is outlined in Grissino-Mayer (1996). Chronology for the MD02-2553 % *G. sacculifer* time-series (Poore *et al*., 2004) is based on 8 AMS ^{14}C dates that were calibrated to calendar years with the OxCal Program (Ramsey, 2001). Larger tree-ring index values represent increased annual precipitation. Increased *G. sacculifer* relative abundance values represent more northerly average position of the Intertropical Convergence Zone, which results in enhanced monsoon circulation.

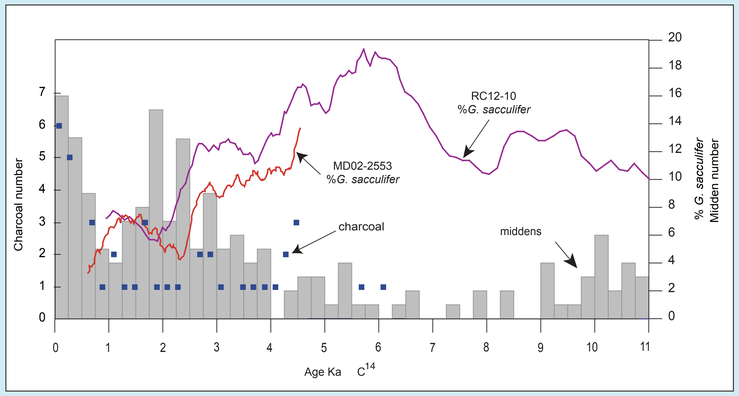

Fig.4 Time-series plot showing occurrence of packrat middens from New Mexico, charcoal fragments in arroyo sediments from the Rio Puerco Basin, New Mexico and *G. sacculifer* abundance variations in core MD02-2553 from the Pigmy Basin and core RC 12-10 from the western Gulf of Mexico (fig. 1). Packrat midden occurrences are grouped into 250 ^{14}C year intervals based on AMS ^{14}C dates on individual middens (Betancourt *et al*., 1993). Charcoal occurrences are grouped into 200 ^{14}C year intervals based on AMS ^{14}C dates on individual charcoal fragments. Marine chronologies assume constant accumulation rates between individual AMS ^{14}C dates (see Poore *et al*., 2003; 2004 for discussion). The *G. sacculifer* abundance plots are smoothed with an 11 year running average for RC 12-10 and a 20 year moving average for MD02-2553. Packrat midden and charcoal records are considered to be proxies for summer rainfall. Packrat middens are hygroscopic. Wet summers hinder preservation of middens whereas dry summers favor preservation of middens. Preservation of charcoal in sediments of the Rio Puerco is a function of the occurrence of large wildfires. Large wildfires produce abundant charcoal on the landscape, which increases the chances that charcoal will be incorporated and preserved in arroyo sediments. Summer rains reduce the occurrence of large wildfires and thus reduce the production of charcoal. Note that occurrences of middens are inversely related to *G. sacculifer* abundance for the last 7 ka. The record of packrat middens in New Mexico is consistent with our interpretation that increased abundance of *G. sacculifer* in GOM sediments reflects northward movement of the ITCZ and enhancement of monsoonal precipitation in the southwest US. Packrat middens with ages between 4,000 and 9,000 ^{14}C years are rare. The marine record indicates the monsoon was most intense from 4.5 to 6.5 ka BP. Packrat midden occurrences increase from 4,000 ^{14}C years to the present while the marine records indicate that the southwest monsoon was declining. The minimum in midden abundance at ca 1,000 ^{14}C years coincides fairly closely with the brief excursion to higher *G. sacculifer* abundances implying a transient increase in monsoon intensity. The general increase of charcoal over the last 4 ka is also consistent with the interpretation that the southwest monsoon has been decreasing since the mid Holocene.

CONCLUSIONS

Comparison of abundance variations in the planktic foraminifer *G. sacculifer* in marine cores from the western and northern Gulf of Mexico with terrestrial proxy records of precipitation from New Mexico support the conclusion that *G. sacculifer* abundance variations are a reliable proxy for changes in the southwest monsoon on millennial and sub-millennial time-scales. The development of marine monsoon proxy provides the potential for constructing a highly resolved, well-dated, and continuous history of the southwest monsoon for the entire Holocene.

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