PROGRESS REPORT

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Evaluation of monument stability and noise associated with campaign and continuous GPS geodesy in the New Madrid seismic zone and other areas of unconsolidated sediment

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Element I

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SUMMARY

This project report is submitted in keeping with requirements as described in the award. Because the start date of the project was July 1, 2002, the report is extremely preliminary, covering only four months. We have not yet obtained significant results, but have purchased and received the necessary GPS geodetic equipment, contacted personnel about monument construction, and forged collaboration with the Center for Earthquake Research and Information (CERI) at the University of Memphis.

INVESTIGATONS UNDERTAKEN

Overview and background: In the winter of 1811-12, three of the most powerful earthquakes in U.S. history struck the New Madrid region of the central United States (Johnston and Schweig, 1996). The zones of severe liquefaction and ground failure associated with these events are >10,000 km^2 (Obermeier, 1988). Because events similar to these have tremendous destructive power were they to occur today, much work has been done in recent years to assess recurrence intervals, strain accumulation, and fault displacements within the New Madrid zeismic zone (NMSZ) (*e.g*. Russ et al., 1978; Russ, 1979; Kelson et al., 1992; 1996; Tuttle and Schweig, 1995; Liu et al., 1992; Weber et al., 1998; Newman et al., 1999). Paleoseismological field evidence is consistent with significant earthquakes occurring every 500 to 800 years (Tuttle et al., 1999). For example, an observation of fault-related folding yielded a slip rate of 5-6 mm/yr across the Reelfoot scarp that translates into a major earthquake (low magnitude 7) every 500 years (Mueller et al., 1999). Determination of displacement rates and recurrence intervals is critical to assessing seismic hazard. Frankel et al. (1996) calculated that the predicted peak ground acceleration expected in 50 years at 2% probability for the NMSZ exceeds that of San Francisco assuming a magnitude 8 event occurs every 1,000 years.

To assess surface strain accumulation in the NMSZ, two groups of investigators began Global Positioning System (GPS) geodetic studies in the region in the 1990's. Initially these groups reached remarkably different conclusions. One group argued for 5-7 mm/yr slip in the southern NMSZ and short recurrence intervals (Liu et al., 1992), whereas the other favored little or no motion within error and, thus, lower hazard with magnitude 7 and 8 events recurring approximately every 1,000 and 10,000 years, respectively (Weber et al., 1998; Newman et al., 1999). Snay et al. (1994) reported rates indistinguishable from zero for the northern NMSZ. Additional measurements of the Liu et al. (1992) network resulted in revised velocity estimates, which yielded less displacement as they included longer GPS data time series (Kerkela et al., 1998; Zoback, 1999; Kenner and Segall, 2000). Nevertheless, the lower rate model is difficult to reconcile with interpretations of high earthquake recurrence intervals from paleoseismology. Recently, attention has been directed to models in which far-field stresses act on either a lower crustal detachment fault (Stuart et al., 1997) or zone of weakness (Kenner and Segall, 2000). Both models predict small average strain rates, on the order of 1×10^{-8} per year, that are difficult to detect with geodetic techniques despite the significant probability of another large-magnitude event in the next few to several hundred years. The real question is whether either model could be distinguished based on any geodetic dataset. To compound the problem, errors associated with monument instability, atmospheric variability, measurement accuracy, observation interval, and site distribution may overwhelm the tectonic signal. Furthermore, Langbein and Johnson (1997) demonstrated that although spatial averaging can reduce the size of both white and random-walk noise components, it does not mitigate their relative effects on the resulting strain accumulation model. Long-term correlations have a large effect on estimating deformation rates.

Importance of monument motion: All geodetic data, including GPS velocity estimates, contain both colored, or time-correlated, and white, or time independent, noise. Because several years may be required to obtain accurate site velocity estimates from GPS data time series in areas of small strain, a variety of errors with different timescales may corrupt the data. In addition, the nature of the error source may change with time. Time-correlated noise includes effects associated with potential monument motion, satellite orbit uncertainties, and atmospheric and local environmental variables (Langbein and Johnson, 1997; Zhang et al., 1997; Mao et al., 1999). Although frequent measurement and averaging can minimize white noise, these methods are less useful for time-correlated noise (Mao et al., 1999). Models that incorporate only white noise, however, underestimate the uncertainty (Johnson and Agnew, 1995; Mao et al., 1999). Regionally correlated noise can be reduced by implementation of a filtering algorithm that subtracts the common mode, nontectonic signals from the GPS time series (Zhang et al., 1997; Wdowinski et al., 1997). This method is most applicable to a relatively dense network of continuous sites.

Monument instability is an important noise source in geodetic studies (Wyatt, 1982, 1989) and is likely a substantial source of time-correlated noise in long-term GPS experiments, introducing spurious position shifts unrelated to tectonic signals (Johnson and Agnew, 1995; Langbein et al., 1995; Langbein and Johnson, 1997). Assumptions of monument behavior generally are not well constrained, particularly for different types of monuments in various geologic settings. Monument motion is likely significant in the NMSZ, which is dominated by unconsolidated sediments of the Lower Mississippi Valley. Detailed study of the error budget, however, has not been undertaken to date within the NMSZ.

Objectives: We propose to conduct a systematic analysis of monument stability and noise characteristics for selected sites in the NMSZ to constrain errors associated with continuous and campaign sites. The purpose is twofold: one, to assess quantitatively noise related to monument motion in different geological substrates; and two, to evaluate the suitability of different monument types in low strain environments. Two sets of two new monuments equipped with continuous receivers will be established, for a total of four new sites. To assess if monument instability in the NMSZ is typical for that in unconsolidated sediment, GPS data time series of the NMSZ will be compared to those from non-bedrock sites in the Caribbean where we have maintained an extensive continuous and campaign GPS geodetic network since 1994. Our objectives are:

- to install two sets of two monuments each along a baseline <10 km long in the NMSZ to measure directly monument instability:
- to determine if monument motion for existing pillars in the NMSZ is similar in magnitude to that of reference sites through analysis of colored noise and random walk motion;
- to assess potential errors associated with different spatial subsets of the total NMSZ network;
- to compare results from measurements in the NMSZ with those from the Caribbean region for both bedrock and unconsolidated sediment sites to determine if the magnitude of errors are comparable in the two regions and
- to evaluate the contribution of seasonal effects and troposheric wet delay variability on noise estimates.

In addition, several new campaign sites will be established in the southwestern extreme of the NMSZ, extending the CERI network into southeastern Arkansas.

RESULTS

This project began in July 2002 and thus is in its infancy. Four Ashtech MicroZ receivers and choke-ring antennae have been ordered and received for installation in winter/spring of 2003. To avoid duplication of efforts and to maximize resources, collaboration has been established with Bob Smalley and Mike Ellis of the Center for Earthquake Research and Information at the University of Memphis.

REPORTS PUBLISHED/SUBMITTED/IN PREPARATION

None to date

ABSTRACTS

None to date

DATA AVAILABILITY

Not applicable

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