Acquisition of a Rapid Sediment Grain Size Analyzer

PI: Matt Kirby, California State University, Fullerton

Funded by: National Science Foundation, 2003

Directorate: Geosciences
Division(s): Earth Sciences
Programs: Instrumentation and Facilities (IF), Research in Undergraduate Institutions (RUI)

<u>**ACQUISITION OF A RAPID SEDIMENT GRAIN SIZE ANALYZER.**</u>
(RUI NSF-02-2 EAR-IF)

PROJECT SUMMARY.

This RUI/NSF Instrumentation and Facilities grant requests funds (~$64,000) to purchase a rapid sediment grain size analyzer. The instrument will be housed in the PI's new sedimentology-based, Paleoclimatology Laboratory at California State University, Fullerton. The acquisition of this instrument will provide a necessary analytical device for the collection of grain size data to compliment the PI's multi-disciplinary, multi-proxy approach to the study of clastic dominated lake systems and their paleoclimatic significance. The requested instrument (an APA 5000, Malvern 2000 Particle Size Analyzer with a Large Volume Liquid Sample Dispersion Unit) is based on cutting edge laser diffraction, user-friendly technology. As a result, the equipment requires no permanent technician support. Application software allows for the development of specific Standard Operating Procedures (SOP) on a sample-type and/or specific research objective basis. The instrument is well known for providing rapid, accurate, and consistent results over a long period of continued use. The user-friendly platform based on SOP's insures that the instrument can be used successfully by a variety of levels of research experienced scientists and students. A nominal fee of $50/100 samples will be charged to collaborators to establish an account (managed by the Cal-State Foundation) to cover expendables (e.g., broken beakers, tubes, stirrers, etc.) and maintenance after the two year warranty expires.

California State University, Fullerton is predominantly an undergraduate university. The Department of Geological Sciences requires that all undergraduate geology majors complete a research thesis to graduate. This instrument will become an important addition to the success and quality of research theses completed within the department. Of the 11 full-time faculty members in the Department of Geological Sciences, 8 (myself included) will benefit directly from the acquisition of the requested instrument. The instrument will be used also for a new research-oriented class offered by the PI entitled *Paleoclimatology*. Other department faculty will be encouraged to use the instrument for class and/or laboratory instruction as well.

The PI is actively developing a long-term research project investigating a north south transect of lake systems along coastal southwestern North America (e.g., Lake Elsinore, Baldwin Lake, Crystal Lake, Big Laguna Lake, etc.). The objective of these lake projects is to understand the geological history of lake dynamics as they relate to regional hydroclimatology. By evaluating a spatially broad region over a variety of temporal scales, the PI intends to understand past hydroclimatology with the goal of predicting the impact of future hydroclimatic change in the study region. The **broader impacts** of this study are twofold: 1) to understand better the natural baseline of hydroclimatic variability in coastal southwestern North America where there is an imminent freshwater shortage crisis, and 2) to involve undergraduates in an active research program that introduces them to field research, laboratory analytical experience, and data interpretation. The **intellectual merit** of this grant is straight-forward: through the acquisition of a rapid sediment grain size analyzer, undergraduate students will have the opportunity to use additional cutting edge technology to obtain data for the interpretation of paleoclimate-related research questions.

The PI's projects are collaborative with several universities and researchers (e.g., University of Southern California, Florida International University, University of Saskatchewan, Syracuse University, Colgate University). None of the collaborative universities own a rapid sediment grain size analyzer. Thus, the opportunity for collaborative projects beyond the PI's present lake studies is likely to expand into new directions over his career.

<u>ACQUISITION OF A RAPID SEDIMENT GRAIN SIZE ANALYZER.</u>
(RUI NSF-02-2 EAR-IF)

PROJECT DESCRIPTION.

1. Introduction.

This RUI-NSF Instrumentation and Facilities Grant requests ~$64,000 for the acquisition of a rapid sediment grain size analyzer. The grain size analyzer will be housed and managed by the Principle Investigator (PI) in the newly established sedimentology-based, Paleoclimatology Laboratory at California State University, Fullerton. Undergraduate and Master-level students as well as other faculty from Cal-State Fullerton and institutions collaborative with the PI will have access to the instrument. Data obtained from the grain size analyzer will be used towards the completion of mandatory undergraduate research theses, Master's theses, and the PI's own, and collaborative, research. These data will be presented at scientific meetings and, ultimately, published in peer-reviewed scientific journals. There are no direct operational costs for the equipment, and there is no required technician support. A nominal fee ($50/100 samples) will be collected by the PI (placed into an account at the Cal-State Foundation) for use of the equipment on a per-use basis to cover expendables only (e.g., broken beakers, tubes, stirrers) and future maintenance after the warranty expires (2 year extended warranty).

Grain size analysis of clastic dominated, lacustrine systems can provide invaluable insight to past climate and its modulation of the sedimentary environment. The use of grain size analysis, however, for interpretation of past climate from lacustrine sediments has not been widely exploited (Fard, 2001). Although, a brief selection of literature on the subject of grain size analysis of clastic dominated lacustrine sediments documents clearly the usefulness of the research method in deconvolving past climates and its modulation of the sedimentary environment (Anderson, 1977; Anderson et al., 1985; Lebo and Reuter, 1995; Retelle and Child, 1996; Moscariello et al., 1998; Goman and Wells. 2000; Anderson, 2001; Francus et al., 2002).

Natural, permanent lakes are rare in coastal southwestern North America, particularly lakes that contain continuous sedimentation throughout the Holocene (Enzel et al., 1989, 1992; Kirby et al., 2002a, 2002b, in prep.). The few extant natural, permanent lakes in the region are clastic dominated such as Lake Elsinore, Baldwin Lake, and Crystal Lake. The rate of clastic sediment accumulation as well as sediment grain size is closely linked to the dynamics of precipitation variability and its modulation of detrital run-off. Changes in lake-level, too, play an important role in the winnowing and transport of littoral sediment into the profundal environment. Sediment grain size analysis, in conjunction with other climate sensitive proxies, will provide a multi-proxy approach to understanding the processes (e.g., climate/precipitation variability) that govern the sedimentary environment in these clastic dominated lake systems. In addition, the new technologies developed for sediment grain size analysis provide a user-friendly platform for the rapid and accurate analysis of samples. As a RUI University, Cal-State Fullerton incorporates undergraduates into the research experience. Within the Department of Geological Sciences, majors must complete a research thesis to graduate. As a result, there is a steady flow of undergraduates pursuing a variety of research projects within the department (~40 majors). Acquiring additional research technologies, such as the rapid sediment grain analyzer, will enhance the undergraduates' research experience by exposing them to new methods of data development and analysis. Specifically, in the PI's Paleoclimatology Laboratory, the rapid sediment grain analyzer will provide an additional "user-friendly" method of analysis for pursuing multi-proxy paleoclimate, lacustrine-based research. The instrument will be used also in the PI's new research-based *Paleoclimatology* course.

2. Types and Focus of Research.

At present, the PI focuses on lacustrine-based, paleoclimate research; although, the PI has worked in the oceanic realm (Andrews et al., 1995; Jennings et al., 1996; Andrews et al., 1998a, 1998b; Kirby, 1998a; Kirby et al., 1998b; Rebesco et al., 1998; Kirby and Andrews, 1999; Hilfinger et al., 2001; Kirby et al., 2001, 2002a, 2002b, 2002c, 2002d, in prep.). The PI is interested, specifically, in using multi-proxy methodologies to understand past climates (e.g., isotope geochemistry, total carbonate, total organic matter, C:N ratios, grain size analysis, x-ray diffractometry). When possible, the PI uses historical calibrations to test the veracity of the paleo-proxy interpretations (Kirby et al., 2001, 2002b, in prep.).

As a new hire at Cal-State Fullerton (8/25/2002), the PI's sedimentology-based, Paleoclimatology Laboratory is presently being renovated with a move-in date of January 2003. The Paleoclimatology Laboratory will house several analytical instrumentation for basic sediment analyses. All geochemical analyses are sent out-of-house to laboratories with which the PI collaborates (e.g., isotope geochemistry at University of Saskatchewan: Dr. Bill Patterson; Florida International University: Dr. Bill Anderson; and, University of Southern California: Dr. Doug Hammond).

The aim of the Cal-State Fullerton Paleoclimatology Laboratory is to develop *sedimentology-based* research projects for undergraduate and Master's theses. The addition of the grain size analyzer will provide an important analytical tool for the development of these sedimentology-based research projects. As stated above, the geochemical portion of the research projects will be completed out-of-house. However, the PI will seek funding to send students to the collaborative geochemical labs for summer research experience and exposure to the geochemical side of paleoclimate research.

The laboratory will have an open-door policy for use by colleagues on individual and collaborative research projects from both Cal-State Fullerton and collaborative Universities.

3. Instrumentation Requested and Justification.

3.1 Instrumentation.

The PI requests funds to acquire an APA 5000, Malvern Mastersizer 2000 Particle Size Analyzer with a large volume liquid sample dispersion unit (~$64,000 with a 2 year extended warranty). Based on the principle of laser diffraction and the inverse relationship between angle of scattered light and particle size, the Malvern 2000 Particle Size Analyzer provides a rapid, accurate, consistent, and user-friendly method of analysis (Malvern Information Brochure, 2002). The instrument has a well-documented reputation for system and mechanical integrity over long periods of continued use. The instrument does not require a permanent technician; the PI will be capable of managing the instrument. The company will provide installation and training of the PI with instrument purchase. A two-year warranty option will be purchased for security. System software is included in the purchase that allows the user the option to create standard operating procedures (SOP) for different sample types. The use of SOP's simplifies the procedure of analysis and insures that samples are consistently measured between different users. This feature is particularly helpful for managing data acquisition in a lab where a variety of undergraduates are using the equipment. The requested instrument allows also for the analysis of large samples in beakers up to 800mL size. Because of the varied character of lake sediments as well as the usual limitations of sample availability, it is useful to have the flexibility of sample size analysis as per the individual research requires. The instrument will be housed in the PI's newly renovated three-room lab/office complex. Purchasing of the instrument will be through Malvern Instuments, Inc. in Southborough, Massachusetts (see Budget for Quotation S13266A). The local company contact for the instrument is Mr. Paul Norlander.

3.2. Justification.

The justification for the acquisition of a rapid sediment grain size analyzer is divided into four parts: **1)** the acquisition of a rapid sediment grain size analyzer is a necessary piece of equipment for developing a fully-functional sedimentology-based, Paleoclimatology Laboratory for multi-proxy paleoclimate research; **2)** the Malvern system provides the most advanced and accessible technology, excellent for an undergraduate-based university; **3)** the acquisition of the rapid sediment grain analyzer will provide an additional instrument for hands-on undergraduate research experience and data interpretation; and, **4)** the Cal-State Fullerton Department of Geological Sciences has 11 full-time, tenure track faculty members. Of this 11, 8 members (including myself) would have direct interest in the use of the sediment grain size analyzer for their research (see Collaborative Potential section). In addition, the PI is actively collaborating with several universities that do not own a sediment grain size analyzer. The PI will allow access to the instrument for external collaborative research projects.

4. Maintenance and Operation.

The acquired rapid sediment grain size analyzer will be housed in the PI's newly renovated three-room lab/office complex. The instrument will be run and managed by the PI; all instrument activity will be documented in a laboratory notebook.

A nominal fee of $50/100 samples will be charged for use. This small fee will be placed into an account at the Cal-State Foundation for purchase of expendables only (e.g., broken beakers, tubes, stirrers, etc.) and for maintenance once the two-year warranty expires. The PI notes, however, that the Malvern product has an excellent reputation for technical and mechanical integrity over long periods of continued use.

The Malvern system requires no permanent technician; the PI will suffice as both lab manager and technician for this instrument. Problems or questions that cannot be addressed by the PI will be sent to the Malvern support desk.

5. Active Research Projects.

5.1 Lake Elsinore Paleohydroclimatology.

Lake Elsinore, located 75km southeast of Los Angeles, represents one of the only natural, permanent lakes in coastal southwestern North America (Figure 1). Located along the Elsinore fault system, Lake Elsinore is a product of rifting associated with the larger-scale "bend" of the San Andreas Fault in Southern California (Mann, 1956). Typical of rift basins, the total sediment thickness beneath Lake Elsinore is massive. A combination of exploratory drill wells and geophysical remote sensing methods indicate sediment thicknesses in excess of 600m; the sediments are described as being mostly fine-grained clastic sediments (Pacific Groundwater Digest, 1979; Damiata and Lee, 1986; Hull, 1990). The modern depositional system at Lake Elsinore is clastic dominated. A combination of eroded detritus via gravity and precipitation run-off processes and eolian transport account for the clastic component of the sediments in Lake Elsinore. Minor components of the sediment include chemically precipitated inorganic calcite, biogenic carbonate (e.g., bivalve carapaces, etc), and organic matter of both terrestrial and aquatic origin.

To date, the PI and his collaborators have demonstrated through a historically calibrated, multi-proxy methodology that the sediments of Lake Elsinore contain information about past climate (e.g., magnetic susceptibility and stable oxygen isotope geochemistry) (Kirby et al., 2002a, 2002b; in prep.). This information on past climate is inferred from a historically calibrated observation between lake-level and magnetic susceptibility (MS) from an 180cm profundal core (core 11) (Figure 2) (Kirby et al., 2002b; in prep.). Figure 2 illustrates clearly that first-order changes in lake-level are recorded by the magnetic susceptibility data. To explain this first-order relationship, a working hypothesis was developed. This working hypothesis states that magnetic susceptibility increases during intervals of high lake level in response to greater regional precipitation and its impact on the erosion and transport of detritus from the surrounding drainage basin into the lake environment and vice versa for intervals of low lake levels

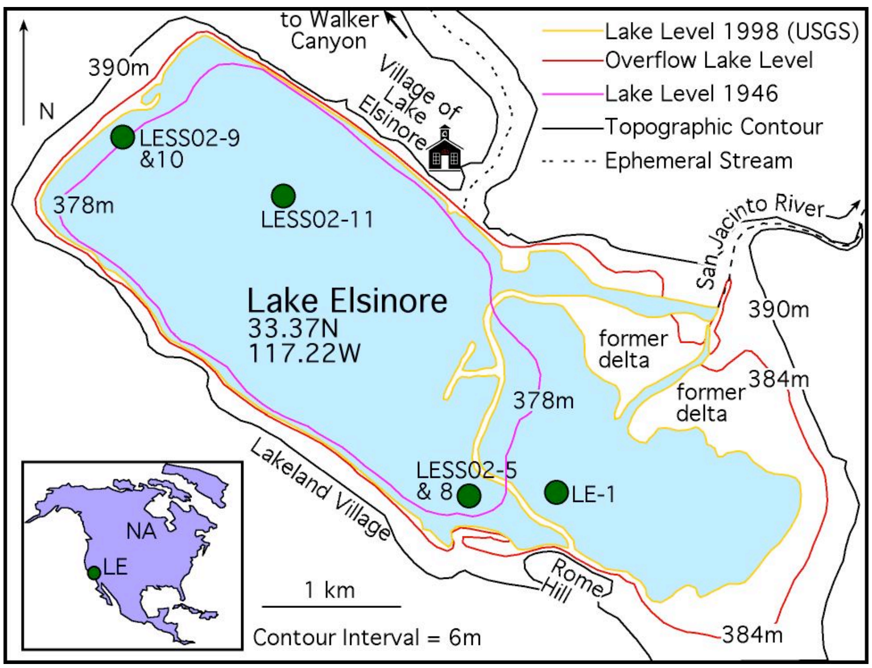

Figure 1. Lake Elsinore Study Site with Core Locations.

(Kirby et al., 2002a, 2002b, in prep.). But, what is the relationship between regional

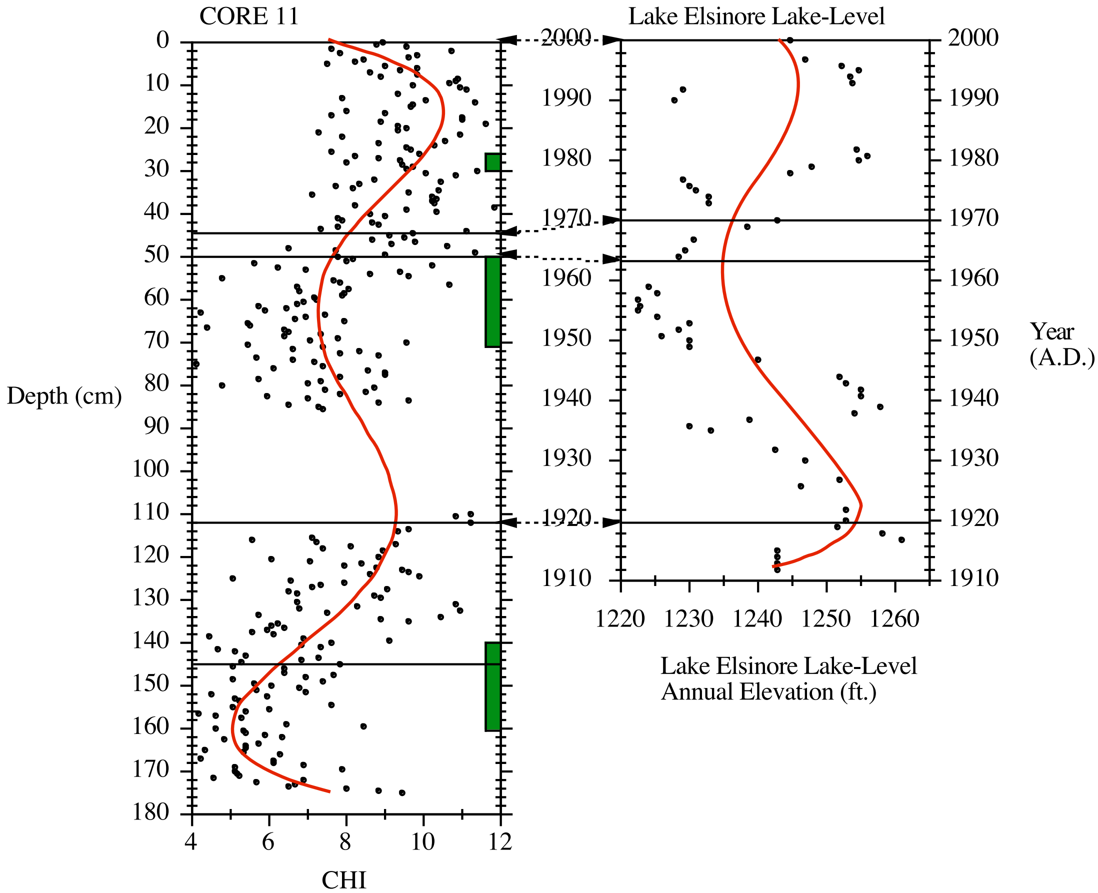

Figure 2. Core 11 MS and Lake Elsinore Lake-Level Data. Black dots denote raw data at 0.5cm intervals. Line is a 5th order polynomial smooth to remove sub-annual and interannual variability. Note: first order relationship indicates that high MS occurs during high lake-level stands. Age control based on radiocarbon dates on total organic carbon, cesium-137, palynology, and trace element concentrations.

precipitation and regional lake-level dynamics?

The relationship between regional precipitation variability and lake-level dynamics is straight forward (Figure 3) (Kirby et al., 2002b). In coastal southwestern North America, the vast majority (>80%) of annual precipitation occurs during the winter months when the polar front jet stream is displaced to the south (Lynch, 1931; Weaver, 1962; Pyke, 1972; Lau, 1988; Redmond and Koch, 1991; Friedman et al., 1992; Ely, 1997; Cayan et al., 1998; Dettinger et al., 1998; USGS, 1998; Kirby et al., 2002b). As a result, storms track more frequently from the moisture-rich source areas of the tropics into the study region. During winters of more frequent storm activity (e.g., El Nino years), lake-levels rise in the study region in response to increased precipitation run-off. During winters of less frequent storm activity, lake-levels decline in the study region in response to less precipitation run-off. Although summer temperatures play a role in seasonal evaporation of the lake water, it is the amount of winter season precipitation that ultimately determines lake-level over time as shown via historical analysis (Figure 3). Thus, any proxy for lake-level or hydrodynamical change is a proxy also for winter precipitation variability. As a result, Lake Elsinore and similar lakes from coastal southwestern North America provide a wonderful opportunity for monitoring past changes in regional hydroclimatology. And, of course, with coastal southwestern North America facing an imminent freshwater shortage crisis, it is critical that research sites are developed that will provide insight to past precipitation variability. Understanding the past will provide better insight to possible future changes in precipitation variability as well as the duration and amplitude of precipitation-induced lake-level changes (i.e., mega-droughts!).

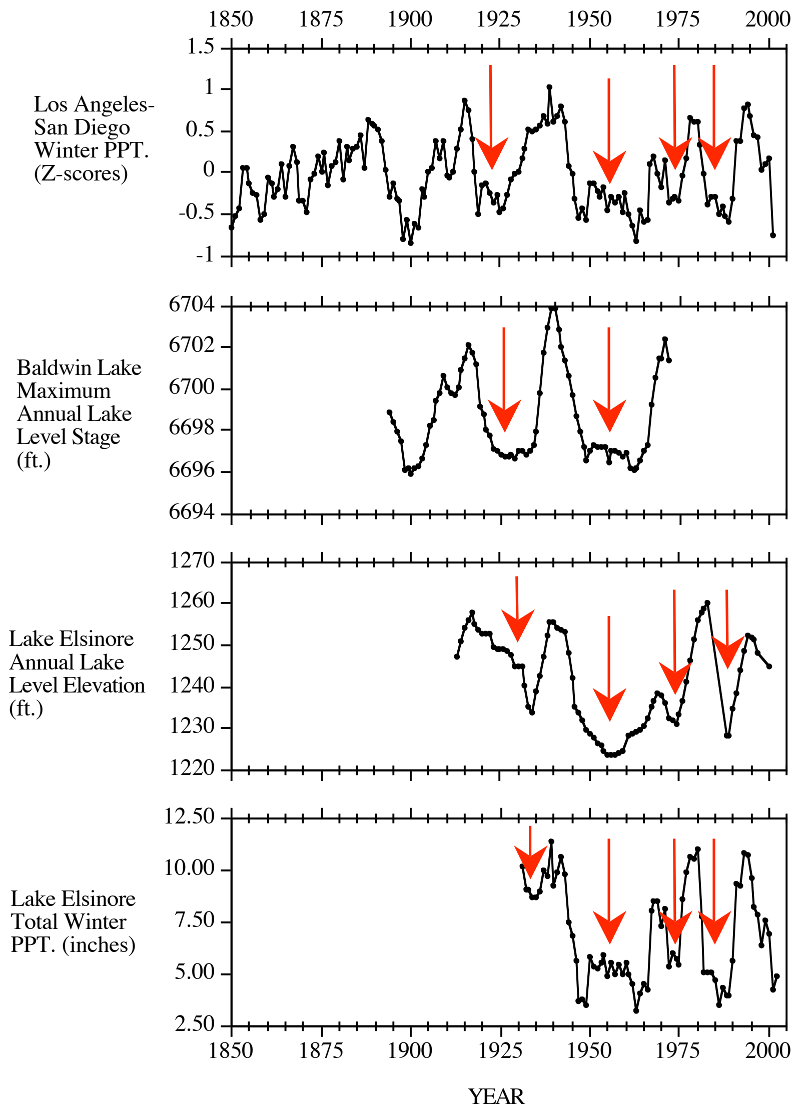

Figure 3. Correlations between regional winter precipitation amount and lake-levels at Lake Elsinore and Baldwin Lake. All data are smoothed by a 5-pt. moving average. Red arrows highlight low lake-level/low precipitation intervals.

$\delta^{18}O_{(calcite)}$ data from a longer sediment core (core 5) from Lake Elsinore's littoral zone support our working hypothesis that high MS represents higher relative lake-level (or "wetter" climate) (Figure 4). Figure 4 shows that the highest $\delta^{18}O_{(calcite)}$ values correspond to low MS values. The ratio of $^{18}O/^{16}O$ in water from an arid environment lake is a function essentially of the ratio of precipitation (P = inflow) to evaporation (E = outflow) (Kelts and Talbot, 1990; Benson et al., 1991, 2002; Li and Ku, 1997; Li et al., 2000). As the P:E ratio decreases, ^{16}O is preferentially removed from the lake basin via evaporation and lake level lowers. As a result, the calcite is precipitated in water with higher $\delta^{18}O$ values; this water imprints its higher $\delta^{18}O$ values onto the calcite oxygen isotope value (Figure 4). In other words, the interpretation of MS and oxygen isotopes from calcite provide corroborative proxies for lake-level change at Lake Elsinore over the past 3,500 calendar years.

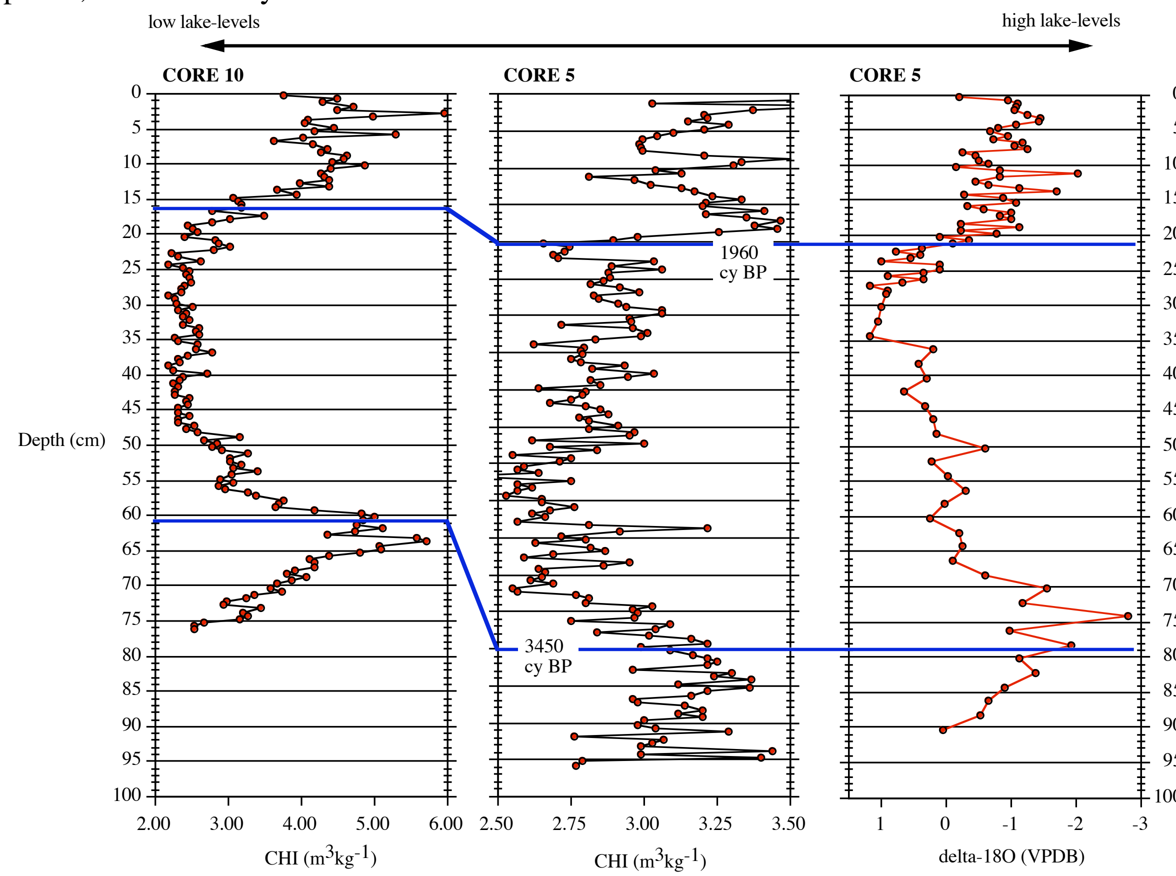

Figure 4. Comparison of MS from Lake Elsinore littoral cores 5 and 10 and oxygen isotope data from core 5. Age control is based on radiocarbon dates on total organic carbon converted to calendar years before present (cy BP). Both independent proxy data support the historically-calibrated relationship shown by Figure 2.

Figure 2 and 5 illustrate also a higher-order level of magnetic susceptibility variability in core 11 from Lake Elsinore. Using the same working hypothesis above, the PI has tentatively linked many of the MS highs with years of higher than average precipitation (Kirby et al., 2002b). In fact, many of the MS highs correlate to El Nino dominated years. Because the lake-level data integrate several years of precipitation variability, it is not unexpected that the higher order MS variability is NOT reflected in the lake-level data (Figure 5). This observation of a higher-order MS signal suggests that the sediments in Lake Elsinore record a range of temporal variability of precipitation. In other words, Lake Elsinore contains both a signal of long-term (decadal-to-millennial scale) hydroclimatic change and short-term (sub-annual-to-interannual scale) precipitation variability. Perhaps, the sediments of Lake Elsinore contain a record of El Nino variability over the length of the 600m sediment package!

Above, it is shown that sediments from Lake Elsinore contain a history of past climate as related to precipitation-driven, lake-level change. It remains unknown, however, why the MS signal records lake-level variability. Using a working hypothesis, it is suggested that MS and lake-level are linked via precipitation and its modulation of erosion. However, this working hypothesis has not been tested in the lake environment. A clear way to test this hypothesis is to analyze sediment grain size at the same intervals as the MS data. If precipitation variability is the primary control on MS variability via erosion, there should be a grain size signal that mimics the MS data (either positively or negatively). Generally, finer grained sediments retain higher MS values (Thompson and Oldfield, 1986; Gale and Hoare, 1991; Benson et al., 2002).

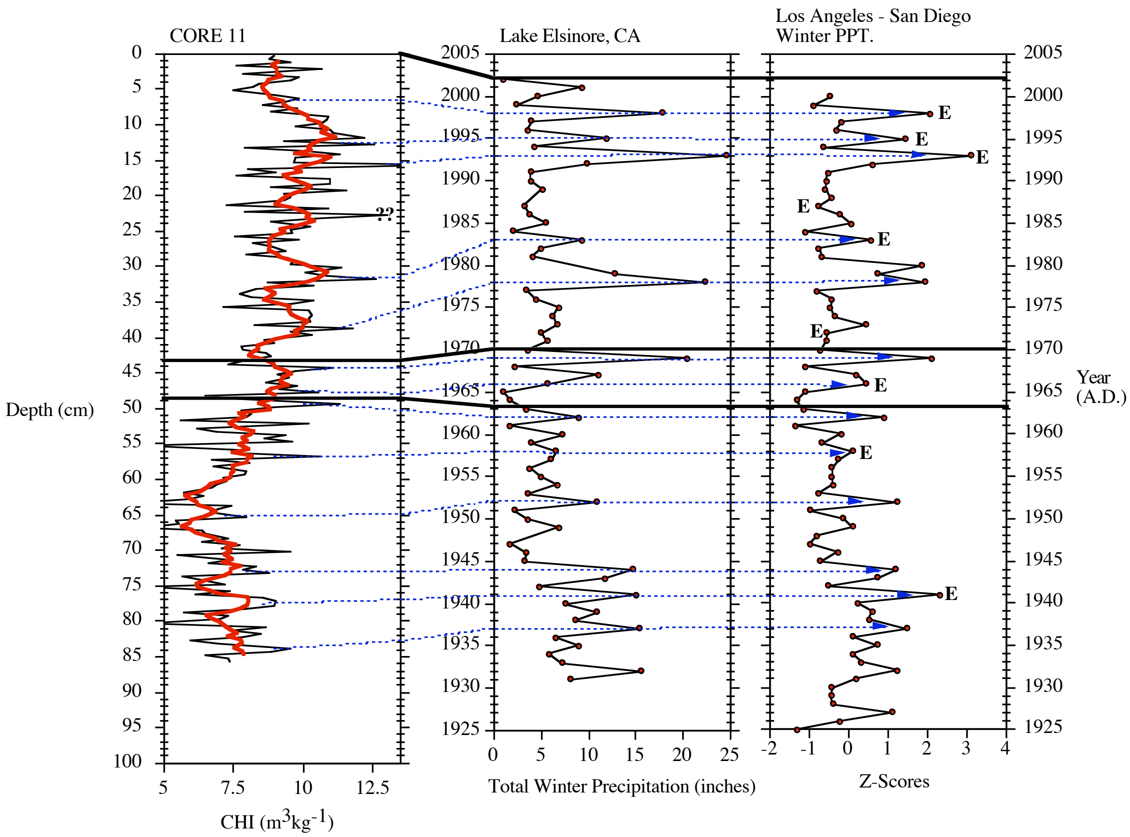

Figure 5. Comparison of core 11 MS and regional winter precipitation. Bold line on core 11 MS graph is a 5-pt. smooth. Fine dashed lines represent the PI's tentative correlations between MS highs and large precipitation years. E = El Nino year (based on NOAA website).

As lake-levels rise in response to increased amounts of precipitation, the influx of fine sediment from the surrounding drainage basin as well as from the winnowing of the littoral sediments should increase. Alternatively, increased precipitation may concomitantly increase the flux of both finer and coarser sediment in response to more vigorous erosion. And, lastly, the MS signal may have nothing to do with grain size. The MS signal may reflect a diagenetic process associated with an increase in organic matter during wet intervals and its affect on magnetic mineral diagenesis (S. Lund, personal comm.). Clearly, the addition of sediment grain size analysis to the study of clastic dominated lake systems in precipitation sensitive regions (i.e., coastal southwestern

North America) will provide important insight to the dynamical controls on sedimentation and in-situ depositional processes (e.g., diagenesis?).

On a finer scale, it will be insightful to determine the extent to which sediment grain sizes reflect higher order climate variability. Can El Nino events be recognized by sediment grain size analysis? Similar studies using color analysis have shown that clastic deposition in South American lakes is directly tied to El Nino frequency (Rodbell et al., 1999; Moy et al., 2002). We propose that the Lake Elsinore site and other lakes from the region will provide a similar opportunity for reconstructing past El Nino variability. Grain size analysis will be an important component of the multi-proxy methodology for answering the El Nino question.

In addition to climate signals, grain size may be an important indicator of lake desiccation. As stated previously, natural, permanent lakes are rare in coastal southwestern North America. They are particularly rare for the Holocene during which most western lakes desiccated completely or for long intervals of time (Stine, 1990; Benson et al., 1991, 1998; Ely, 1991; Enzel et al., 1989, 1992; Li and Ku, 1997). One of the potential problems presented by a reviewer of the PI's recent NSF-WCR grant proposal (NSF-02-101: not funded) was that Lake Elsinore and similar lakes from the region may contain lengthy sediment hiatuses. Of course this may be true; however, if the sediment hiatuses can be properly constrained, the researcher can still extract meaningful climate information from the intervals where sediment exists. Furthermore, the absence of sediment in an arid environment lake is also insightful because it represents the absence of water and thus an interval of aridity! Grain size analysis will be an important tool for identifying the location of these possible sediment hiatuses (in addition to other proxies). During lake desiccation, eolian processes may preferentially remove finer grained sediment producing deflation horizons with coarser-sized sediment left intact. Anderson (2001) showed that rapid infilling of lakes following periods of desiccation or dry intervals are characterized by an increase in coarse quartz grains associated with inflow of stream discharge and its increased competency.

Perhaps the best way to understand the relationship between grain size and lake dynamics will be a modern study of lake sediment processes. Beginning this summer, the PI and a student will begin a monitoring project using surface sediment transects, drainage basin samples, and sediment traps. These samples will be analyzed for a variety of properties including grain size (grain size pending, of course, the acceptance of this grant). By studying the modern system, the PI will develop a better understanding of the processes that govern Lake Elsinore's sedimentary environment.

5.2 Baldwin Lake Paleohydroclimatology.

Baldwin Lake is a naturally dammed alpine lake located within the San Bernardino Mountains at 2024 m elevation (110km SE of Los Angeles). Baldwin Lake is located at ~1700 m higher than Lake Elsinore and ~70km NE of Lake Elsinore. A comparison between the two lakes will provide important insight to regional spatial-temporal hydroclimatology. A short (~3m) core has been collected and analyzed for basic sedimentological attributes from Baldwin Lake (Figure 6). Similar MS signals are recognized between both lake basins (i.e., Elsinore and Baldwin) suggesting a spatially coherent control on their respective sedimentary environments (Figure 6). Surrounded by the San Bernardino Mountains, Baldwin Lake should have an interesting grain size history of precipitation/run-off modulated erosion. Using a multi-proxy methodology, Baldwin Lake will provide an alpine history of past hydrodynamics for comparison to Lake Elsinore.

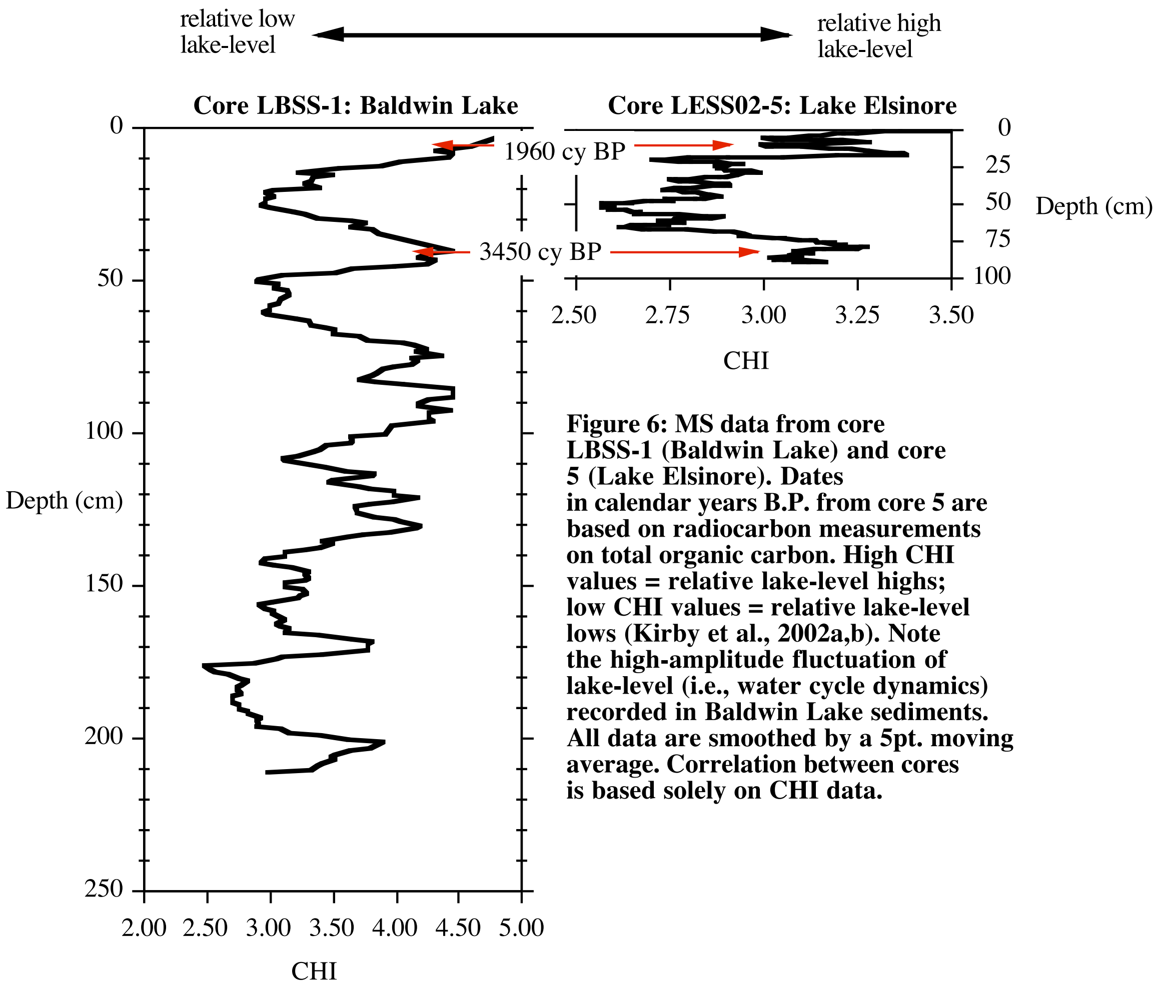

Figure 6: MS data from core LBSS-1 (Baldwin Lake) and core 5 (Lake Elsinore). Dates in calendar years B.P. from core 5 are based on radiocarbon measurements on total organic carbon. High CHI values = relative lake-level highs; low CHI values = relative lake-level lows (Kirby et al., 2002a,b). Note the high-amplitude fluctuation of lake-level (i.e., water cycle dynamics) recorded in Baldwin Lake sediments. All data are smoothed by a 5pt. moving average. Correlation between cores is based solely on CHI data.

6. Long-Term Research Goals.

The long-term research goals for the PI are three fold: **1)** to establish a sedimentology-based, Paleoclimatology Laboratory; **2)** to continue the development of a coastal southwestern North American north south transect of lacustrine-based, paleoclimatic research; and, **3)** to develop and maintain an undergraduate and master's research program.

1) The establishment of a sedimentology-based, Paleoclimatology Laboratory requires a minimum of several analytical instruments. The PI has obtained, with start-up funds (~$35,000) a variety of coring devices (for acquiring sediment samples), a muffler oven (for loss-on-ignition analysis to determine total inorganic carbonate and total organic matter; Dean, 1974), a Bartington MS2 magnetic susceptibility meter and loop (for measuring the environmental magnetism of sediment samples), and a binocular microscope (for microfossil counts). Together, these instruments allow for the acquisition of sediment samples and their basic development and characterization. The PI has a pending grant proposal through the American Chemical Society/Petroleum Research

Fund requesting funds to purchase a Coulometer for high precision carbonate analysis. The acquisition of a Coulometer would compliment the loss-on-ignition analyses especially for low carbonate samples such as those found in many lakes from coastal southwestern North America. In this RUI NSF-IF grant proposal, the PI requests funds to purchase a rapid sediment grain size analyzer. As discussed in the Active Research section, a rapid sediment grain size analyzer would be invaluable to the research of clastic dominated lake systems for a variety of reasons.

The addition of the rapid sediment grain size analyzer (and Coulometer) would complete the PI's sedimentology-based Paleoclimatology Laboratory. Furthermore, these instruments are all low maintenance and user-friendly. The PI has decided purposely to develop a sedimentology-based lab because of its low maintenance and user-friendly capacity. The reason for the PI's decision to develop this type lab is based on the undergraduate nature of Cal-State Fullerton. By developing a sedimentology-based, Paleoclimatology Laboratory, the PI can expose undergraduates to a variety of sediment analysis techniques that do not require years of training or maintenance by an on-hand technician. The students, therefore, can acquire a variety of sediment data in a short amount of time with minimum technical difficulties. As a result, the undergraduates are left with ample time to develop the necessary interpretative skills and writing skills that are essential to good science. It is the goal of the PI to immerse his students in the active participation of meaningful research, data acquisition, and data interpretation and development. A sedimentology-based Paleoclimatology Laboratory will provide the broad spectrum of analytical techniques, experiences, and interpretative skills necessary for the development of young, future scientists.

2) It is the long-term research goal of the PI to continue the development of a coastal southwestern North American paleoclimate lake-based north south transect. There are no published climate-based lake studies south of Owen's Lake in coastal southwestern North America. This fact is surprising in the context of southern California's large population and severe water shortage crisis. Lake sediments provide a natural barometer of regional hydrodynamics, and thus, they are an obvious source of information on past climate. To understand better future water crises (e.g., droughts), it is essential that lake studies from coastal southwestern North America are developed to assess the magnitude, frequency, and duration of past hydrodynamic events. Through the study of many lake sites (e.g., from north to south: the Devil's Pothole, Crystal Lake, Lost Lake, Lake Elsinore, Baldwin Lake, Lake Henshaw, Big Laguna Lake, etc.), the PI will develop a long-term history of the spatial and temporal variability of hydrodynamics in coastal southwestern North America. These records can then be compared to marine records from the adjacent basins of the eastern Pacific to assess the influence of large-scale ocean-atmosphere dynamics on western North American climate over time (Heusser, 1978; Kennett and Ingram, 1995; Cannariato and Kennett, 1999; Hendy et al., 2002). Over the course of the PI's career, lakes will be studied south into the Baja of California and western Central America. It is likely also that collaborative projects will involve lakes from other sites not presently considered.

3) The PI seeks also to develop an active undergraduate and master-level research program. Based on the PI's own undergraduate and graduate research experiences, there are several keys to the development of a successful research program. First, the PI must have a *variety* of active *research projects* that present a broad spectrum of research questions and methodologies. Although it is just the PI's first year as a professor, he has developed a variety of research projects. At present, the PI has an undergraduate (Erik Paquette) studying the urban heat island effect on southern California's recent (past 150 years) climate, and a master's student (Jennifer Bukey) researching Lake Elsinore's recent (past 500 years) productivity. Second, the PI must develop *focused research projects* for his students. It is important that your student's play an active role in the development of their projects, but at the undergraduate level, and even the master's level, project guidance is a necessary skill to keep the student focused for completion in a timely manner. Third, the PI must have *reasonable expectations*. There are significant differences between what an undergraduate and a masters student can accomplish. Recognizing this difference and guiding your students along the appropriate paths will enhance their success. Fourth, the PI must have functional laboratory space and facilities. Research is a verb! The passion a student develops for research comes from their experiences in the lab. Of course, for geologists, a lab can be in-doors or out-of-doors. For this PI's research, each student will experience the process of sample collection (out-of-doors) and data acquisition, development, and interpretation (in-doors). As previously shown, the PI will soon be occupying a newly renovated three-room lab/office complex that presently houses several sedimentology-based analytical instruments. Fifth, the PI must have a pleasant demeanor!

7. Undergraduate Involvement.

Undergraduate Geology majors (n = ~40 majors) at Cal-State Fullerton must complete a research thesis to graduate. Mandatory research theses are not common among American universities, particularly universities as large as Cal-State Fullerton (n = ~33,000 students). By involving undergraduates in active research projects, the student is provided an opportunity to experience research as an active participant. Because the nature of the PI's research is multi-disciplinarian, the PI has access to students from other departments as well as the Department of Geological Sciences. The PI's first undergraduate thesis is being completed this summer by a "liberal studies" major whom has a strong background in geology and geography. Similarly, the PI's first master's student is from the Environmental Sciences Program; Jennifer was a biology major and a geology minor as an undergraduate. To broaden the undergraduates research experience, each student working with the PI will have a two-part project: a field component and a laboratory component. The field component will consist of sample collection at the student's research site(s). The laboratory component will involve the use of analytical instrumentation for the acquisition of data.

In addition to the completion of research senior theses, the PI will have his students present their results at regional and/or national scientific meetings (e.g., GSA, AGU, AAG). Furthermore, the PI will publish the results as the research permits (co-authorship with the student) in peer-reviewed scientific journals. The PI was fortunate to publish his undergraduate thesis results in Marine Geology (Kirby et al., 1998b), an experience that "opened-the-doors" to the excitement and fulfillment of scientific publishing.

8. Use of Instrumentation for Undergraduate Education.

The PI is developing presently a new upper-division course entitled *Paleoclimatology*. This course will consist of two parts: 1) the methods for interpreting past climates, and 2) the interpretation of climate proxy data. For both parts, the course will use a combination of textbooks (Bradley's <u>Paleoclimatology</u> and Cronin's <u>Principles of Paleoclimatology</u>) and research articles. One of the major projects of the course will be a hands-on mini-research project. The class will obtain cores from one of the lakes studied by the PI. They will characterize the core using several sedimentology-based instruments in the PI's Paleoclimatology Laboratory (e.g., loss-on-ignition, MS, grain size, micro-fossil counts). The PI will provide age control. Using this multi-proxy methodology, the students will interpret the data and submit a final paper summarizing their results and paleoclimatic interpretations. Through the combination of in-class lecture and discussion and on-hands research, the students whom take this course will experience both the theory and practice of paleoclimate research.

The instrument will be available also to other faculty whom wish to incorporate lab exercises into their courses. I will encourage our new hire in sedimentary geology/stratigraphy to use my lab as necessary for teaching purposes. There will be no fee for class-based instrument use.

9. Collaborative Potential.

Rapid sediment grain size analyzers are surprisingly uncommon in the academic community despite the insight they clearly afford the researcher. Here, at Cal-State Fullerton, the acquisition of a sediment grain size analyzer will benefit several researchers. Out of eleven full time faculty in the Department of Geological Sciences at Cal-State Fullerton, at least 8 (including myself) pursue research projects wherein the use of a sediment grain size analyzer would be beneficial. These include: 1) Phil Armstrong (Quaternary Geology, Active Tectonics, and Basin Analysis), 2) Jerry Brem (Economic Mineral Deposits, Volcanic Processes, Geochemistry), 3) John Foster (Engineering Geology, Neotectonics, and Quaternary Geology), 4) Jeff Knott (Quaternary Geomorphology, Paleoclimates of Playa Lakes, and Tephrochronology), 5) Richard Laton (Hydrogeology, Environmental Geology, and Applied Field Problems), 6) Brady Rhodes (Quaternary Structure and Stratigraphy), and 7) New Hire (8/2003) in Sedimentary Geology and Stratigraphy.

Outside of Cal-State Fullerton, the PI has several universities with whom he collaborates, none of which own a rapid sediment grain size analyzer. These universities include: 1) University of Southern California (Steve Lund, Chris Poulsen, and Doug Hammond), 2) Florida International University (Bill Anderson), 3) University of Saskatchewan (Bill Patterson), 4) Syracuse University (Hank Mullins), and 5) Colgate University (Adam Burnett). Each of these collaborations would benefit from the acquisition of a rapid sediment grain size analyzer. In fact, the PI would become involved in a variety of lake and oceanic projects that are not regionally isolated to coastal southwestern North America. Through these collaborations and their use of the grain size analyzer, the PI will have the opportunity to expose his students to a wide range of research projects and potential future degree options.

10. Project Successes and Future Funding.

It is important to note that the use of the requested rapid sediment grain size analyzer is NOT contingent on laboratory funds. With the exception of radiocarbon dating and some core extraction techniques, lacustrine-based paleoclimate research is relatively low cost. At present, the PI has >50m of sediment from Lake Elsinore stored in the Cal-State Fullerton Department of Geological Sciences Cold Storage Facility. Baldwin Lake sediment core samples are stored there as well. Because the PI's research sites are relatively close-to-home, there are no direct costs of travel. Therefore, the acquisition of additional sediment samples is an easy and on-going task. Sediment grain size analysis will be a staple methodology in the PI's lab; consequently, the instrument will be used from the moment it is purchased. In other words, the funding of this grant is not a Catch-22…i.e., funding of the instrument depends on grants for research that depend on an instrument for analysis to get the initial funding!

11. Inventory of Existing Equipment and Technician Positions.

Cal-State Fullerton does not own any comparable items of equipment as the requested rapid sediment grain size analyzer. The Department of Geological Sciences does not employ a laboratory technician nor is a lab technician required for this equipment request.