DIGITIZATION OF A HISTORIC DATASET: THE WIESLANDER CALIFORNIA VEGETATION TYPE MAPPING PROJECT

MAGGI KELLY[1] AND BARBARA ALLEN-DIAZ
Department of Environmental Sciences, Policy and Management, 137 Mulford
Hall, #3114, U.C. Berkeley, Berkeley, CA 94720-3114

NORMA KOBZINA
Marian Koshland Bioscience and Natural Resources Library, 2101 VLSB #6500,
U.C. Berkeley, Berkeley, CA 94720-6500

ABSTRACT

In the 1920s and 1930s Albert Everett Wieslander and several others explored much of California's wilderness sampling vegetation, taking photographs, collecting specimens, and drawing detailed maps of what they found. The collection is now known as the Wieslander Vegetation Type Mapping (VTM) collection, and the entire survey encompassed nearly seventy million acres of the state, covering most of the wild areas exclusive of the deserts and the larger agricultural areas. These data represent a valuable resource for comparative and conservation ecology. We are digitizing the entire project, and making it available to researchers and the public. The current "VTM Digitization" Project, as it is known, is described in this article, and is a collaborative effort by teams at University of California Berkeley and University of California Davis, funded by the U.S. Forest Service and U.S. Department of Agriculture's Cooperative State Research, Education and Extension Service. The VTM Digitization Project aims to digitize the entire VTM collection for use in ecological and geospatial analyses, and to facilitate access and distribution of the data by researchers and interested parties. This article describes our efforts at making the VTM plot data, maps and photographs digital, spatially referenced, readily available, and web-accessible via an Internet-based Geographic Information System (webGIS) application. In addition, we discuss potential uses for the data and caveats associated with its use, particularly spatial accuracy.

Key Words: VTM dataset, webGIS, digital database, California plant communities.

The 18th through early 20th century was a time of tremendous exploration of the landscape of the United States, and the data generated by these surveys include information about pre- and early settlement vegetation. The Public Land Survey System (PLS) which began in 1785 with the Land Ordinance Act is probably the best known example (Iverson 1988; Buisseret 1990; White and Mladenoff 1994; Manies and Mladenoff 2000; Manies et al. 2001), but there are others, including numerous 18th and 19th century land surveys, settlement maps, and deeds (Siccama 1971; Russell 1981; Foster et al. 1998). While these efforts were land surveys rather than botanical ones, valuable vegetation data are contained in these collections, and in many states, they provide the first statewide vegetation map showing the natural environment before extensive changes associated with European settlement. Many researchers are now interested in these collections, recognizing their importance for historical ecological research, as well as to establish baselines for analyzing current patterns of land use change (Galatowitsch 1990; White and Mladenoff 1994; Minnich et al. 1995; He et al. 2000; Schulte et al. 2002). As an example, Schulte and Mladenoff (2001) claim that the PLS records provide the

"broadest coverage (Ohio to the west coast) and finest spatial resolution (one square mile) of any pre-settlement data source".

Although there are numerous examples of coastal maps of California dating from the 16th century, surveying of the land from the Mexican border northward did not begin until the early 19th century (Heckrotte and Sweetkind 1999), and statewide mapping endeavors began in earnest in the mid-19th century with statehood. The California PLS survey began shortly after 1851, and the data collected included hydrography, vegetation, and natural resources, as well as cultural details (Buisseret 1990; Heckrotte and Sweetkind 1999). Further statewide efforts at mapping the natural landscape followed, including an effort by the California Geological Survey at statewide biological resource mapping in the 1860s (Ertter 2000). The effort was abandoned in 1873 as a result of several factors, including politics, personnel, and poorly estimated costs.

Following these efforts, Albert Everett Wieslander and several others, with funding from the Forest Service and other federal, state and county agencies, began mapping California's vegetation in an effort that was described later as the most important and comprehensive botanical map of a large area ever undertaken anywhere on the earth's surface (Jepson et al. 2000). The Wieslander crew explored much of California's wilderness sampling vegeta-

[1] Author for correspondence, email: mkelly@nature.berkeley.edu

TABLE 1. SOME POTENTIAL USES OF THE VTM DATASET.

Data type	Dataset content	Potential uses
Plot Data	18,000 plots	—Quantitative analysis of vegetation change at landscape or larger scales.
Plot Maps	150 15- and 30-minute USGS topographic quadrangles	—Use in relocating plots for analysis of disturbance: e.g., historic forest stand structure in forests across a gradient of Sudden Oak Death infestation.
Vegetation Maps	350 15- and 30-minute topographic quadrangles	—Retrospective mapping to examine vegetation alliance changes.
		—Compare mapping methods in key areas such as Yosemite, examining e.g., average size of polygon, minimum polygon, and number of different mapping units.
Photographs	3100 black and white photographs	—Graphic examples of land-use change from stand to landscape-scale.
		—Evidence of disturbance (e.g., fire, logging).

tion, taking photographs, collecting specimens and drawing detailed maps (Wieslander 1935b; Colwell 1977). The natural vegetation mapping was carried out by the U.S. Forest Service (USFS) California Forest and Range Experiment Station in Berkeley (Colwell 1977). Mapping continued using a protocol developed by Wieslander until it was stopped during World War II. By then, 16 million ha had been mapped (Wieslander 1961; Colwell 1977). The well-preserved collection is now known as the Wieslander Vegetation Type Mapping (VTM) collection, and the entire survey encompassed nearly 28 million ha, covering most of the state's natural areas exclusive of the deserts and the larger agricultural areas. The collection represents a fascinating snapshot of California vegetation in the early part of the last century, and represents a valuable resource for foresters, ecologists, land managers, and others interested in the natural environment of early 20th century California, and land use changes since then. For example, the collection has been used in part as a basis for the statewide California Gap Analysis maps produced decades later (Davis et al. 1995; Walker 2000).

We are digitizing the collection, and making it available to researchers and the public. The current "VTM Digitization" Project is a collaborative effort by teams at University of California Berkeley (UCB) and University of California Davis (UCD), funded by the USFS, and U.S. Department of Agriculture Cooperative State Research, Education and Extension Service (USDA CSREES). The VTM Digitization Project aims to digitize the entire VTM collection for use in ecological and geospatial analyses, and to facilitate access and distribution of the data by researchers and interested parties. This article describes our efforts at making the VTM collection digital, spatially referenced, readily available, and web-accessible via an Internet-based Geographic Information System (webGIS) application. In this paper we aim to: 1) describe the collection, 2) alert readers to the digitization project, 3) describe the methods used to complete the digitization, and 4) discuss the potential uses for the

data, as well as some of the caveats in using the data.

The Vegetation Type Mapping (VTM) Collection

The VTM collection consists of five components, four of which are described here: 1) Plot data gathered on more than 18,000 plots around the state that include floristic and environmental detail, 2) Plot maps depicting the locations of plots sampled, 3) Vegetation maps, showing hand drawn polygons of forest types, and their associated species, and, 4) Landscape photographs and associated information about location and content of the photographs. The team also collected herbarium specimens for every species recorded on the vegetation maps or in the sample plots (Ertter 2000). We have not begun incorporating the herbarium specimens into this digital collection, but we are providing a link between our webGIS system and the Jepson Herbarium Specimen Catalog.

Plot Data

There are approximately 18,000 plots statewide, concentrated primarily along the central and southern coastal ranges, and along the Sierra Nevada. These plots were surveyed not only as a check on the vegetation mapping, but also to survey the diversity of California vegetation types for details such as species composition, size and stand density of trees and shrubs and depth of leaf litter. These sample plots were located across a gradient of vegetation types, and the historic records contain data regarding tree stand structure (number per diameter class), percent cover of dominant overstory and understory vegetation by species, soil type, parent material, leaf litter, elevation, slope, aspect, parent material, and other environmental variables.

Details of the plot design are as follows (Wieslander 1935a; Wieslander 1935b). Each plot was rectangular in shape with the longer axis running upslope. The plots were 800 m^2 in size in forests, and 400 m^2 in scrub and chaparral communities. For example, the 400 m^2 plots were laid out using

two chains (ca. 40 m) long and one-half chain (10 m) wide, and divided into 100 squares (ca. 4 m^2). In both types of plots, the dominant species within each milacre was recorded. When less than 50% of the square was vegetative cover, ground surface characteristics such as bare ground, rock outcrops or tree trunks were noted. A summary of the squares within the rectangle plot was provided, noting the average height of the dominant species (to the nearest 0.5 ft or 15 cm). At the same time, trees greater than 10 cm in dbh within 10 m of either side of the center-line were tallied by species and diameter class. In both types of plots, additional information such as slope, soil character and year of last burn was recorded (Wieslander 1935a; Wieslander 1935b).

All plot data was stored on paper data sheets, and individual plots were numbered according to U.S. Geological Survey (USGS) topographic quadrangle map name, quad section number and plot number. There are about 150 original maps remaining in the

collection. A snapshot of the plot data is found in Figure 1a.

Plot Maps

The VTM plot maps show the locations of all the individual plots surveyed by the original VTM crews. Hollow circles of about 3.5 mm in diameter depicting the location of the plots were stamped in red ink on USGS topographic maps (editions of 1893–1920, reprinted in the 1930s) that had been cut into sections, mounted on canvas, and folded, to facilitate use in the field. This allowed for repeated folding along the seams, without loss of mapped information. Unfortunately, the resulting maps were not dimensionally stable, and 80 years of use, temperature extremes, and other factors have warped many of the plot maps. This has required us to take steps in the georeferencing process to reduce these errors, described below. The plot map collection comprises about 150, 15-minute (1:62,500 scale) and 30-minute (1:125,000
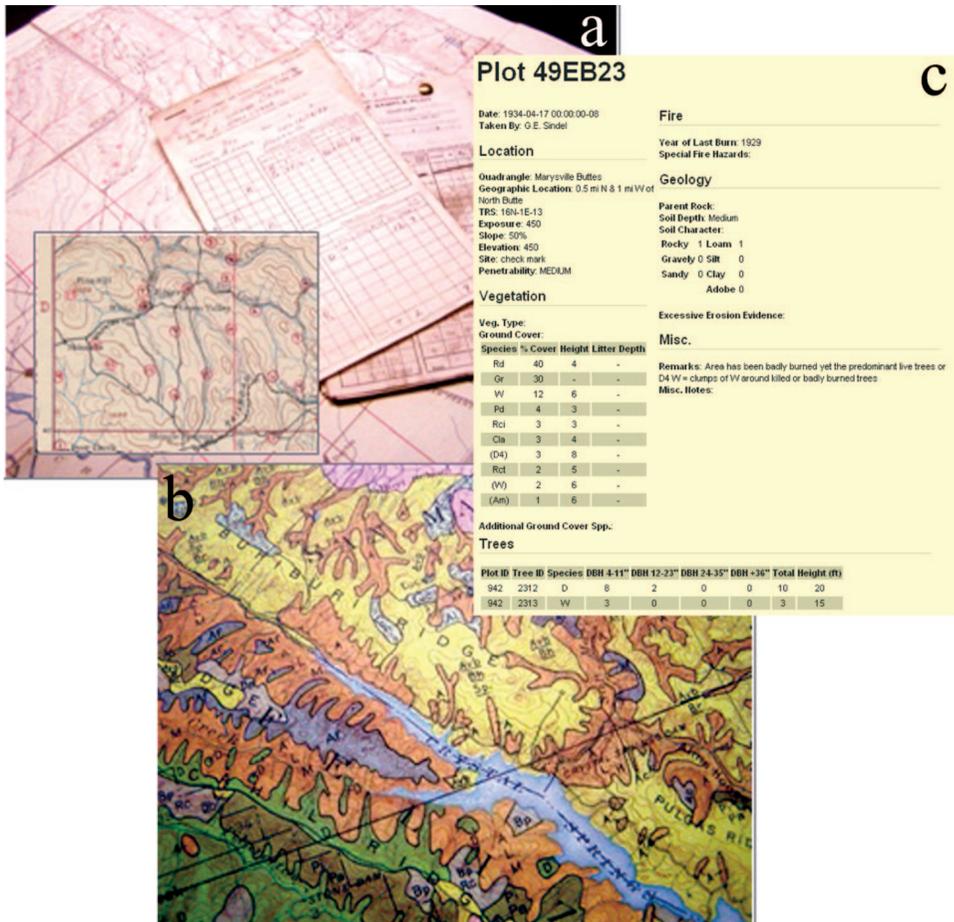
FIG. 1.   Plot and vegetation map data examples: a) scanned plot maps and plot data sheets, b) a sample vegetation map, and c) a sample of the database return for one plot.

Map/Data Presence
- Plot Data
- Plot Map
- Plot Map & Data
- Vegetation Map
- Counties
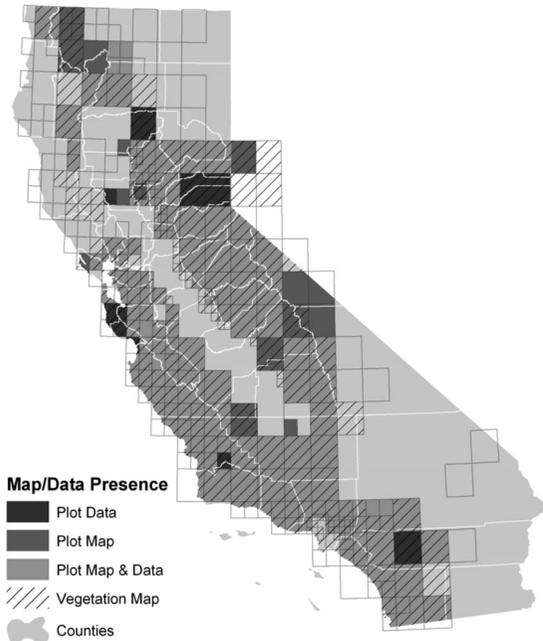
Fig. 2. Inventory of VTM plot maps in California. We have produced inventory maps for other parts of the collection. These can be found at: http://vtm.berkeley.edu/

scale) USGS quadrangles, primarily concentrated along the central and southern coastal ranges, and along the Sierra Nevada. Figure 2 displays our inventory of the plot maps and Figure 1a shows an example of the plot maps and data sheets.

Vegetation Maps

The vegetation type maps were mapped in the field by VTM crews, directly upon 15-minute (1: 62,500-scale) topographic quadrangles by direct observation, and "sketching from ridges, peaks, and other vantage points", and supplemented by sample plots (Wieslander 1935b). With average conditions, it took a two-man crew from six to eight weeks to complete the field work for a 15-minute quad of about 6,070 ha (Wieslander 1935a). Plant communities were mapped to a minimum of 16 ha (Colwell 1977). Dominant plant species were mapped, while understory vegetation information was collected in the sample plots. The vegetation mapping scheme, since it was done in the field via overlooks and remote vantage points was by necessity driven by overstory species recognition (i.e., "the dominant vegetation visible externally" (Wieslander 1935a)). The VTM method used two vegetation classification concepts: they mapped "mosaic types" which are complex vegetation conditions that result from fire or other disturbances, or pure and mixed stand conditions which they associated with natural plant associations (Wieslander 1935a).

The mapped products include map sheets over-

printed in color on 15- and 30-minute USGS topographic quadrangles, and simplified, uncolored blue-line print sheets. Some areas of the state have "zoomed-in" vegetation maps drawn on 6- and 7.5-minute USGS quads. The major vegetation types are shown in different colors and separated by ink lines (Colwell 1977). These are further subdivided on the map into pure and mixed stands, with notation on species composition. The teams used a protocol designed to be useful for engineers, foresters, and managers, and attempted to group vegetation types by their fire hazard characteristics, uses, or economic importance.

There are about 330 of these detailed maps in the collection, covering about 16 million ha. Some were published, and some remain unpublished. Figure 1b shows an example of a vegetation map from the San Mateo area. The plot data sheets, plot maps, and vegetation maps are currently curated by Dr. Allen-Diaz in the Environmental Sciences, Policy and Management Department in the College of Natural Resources at UCB.

Photographs and Associated Data

There are approximately 3100 black and white photographs (9.2 × 13.6 cm) from 1920–1941, and approximately 100 color topographic maps. Many of the photographs are keyed to USGS topographical maps. For these photographs, the location of the place where the photos were taken is written in red pen on the maps, with an arrow marking the vantage point and view of the photo. Some of the photographs are "panorama" style images, but most are focused on a stand (see examples in Fig. 3). The photographs document the typical and atypical subtype, wider species, timber stand conditions, range of variation, and consequences of land use and cultivation, grazing, logging, mining and fire. The main photographer was Albert Wieslander. A second "series" was done by Richard C. Wilson, a UCB School of Forestry graduate. Several other photographers, including C. Raymond Clar, participated in the project. The Marian Koshland Bioscience and Natural Resources Library at the University of California, Berkeley houses the VTM Photographs Collection.

METHODS AND RESULTS TO DATE

Initial Preparation

In order to create a complete and linked database accessible to the public and to researchers, we needed to make all parts of the collection digital, index each component by its spatial location, and develop a web tool for users to query, view, and download data from the database. These are described in turn here. Similar efforts have been made in other states (e.g. Iowa and Wisconsin) with interesting results (Anderson 1996; Schulte et al. 2002). We refer to some of the lessons learned in
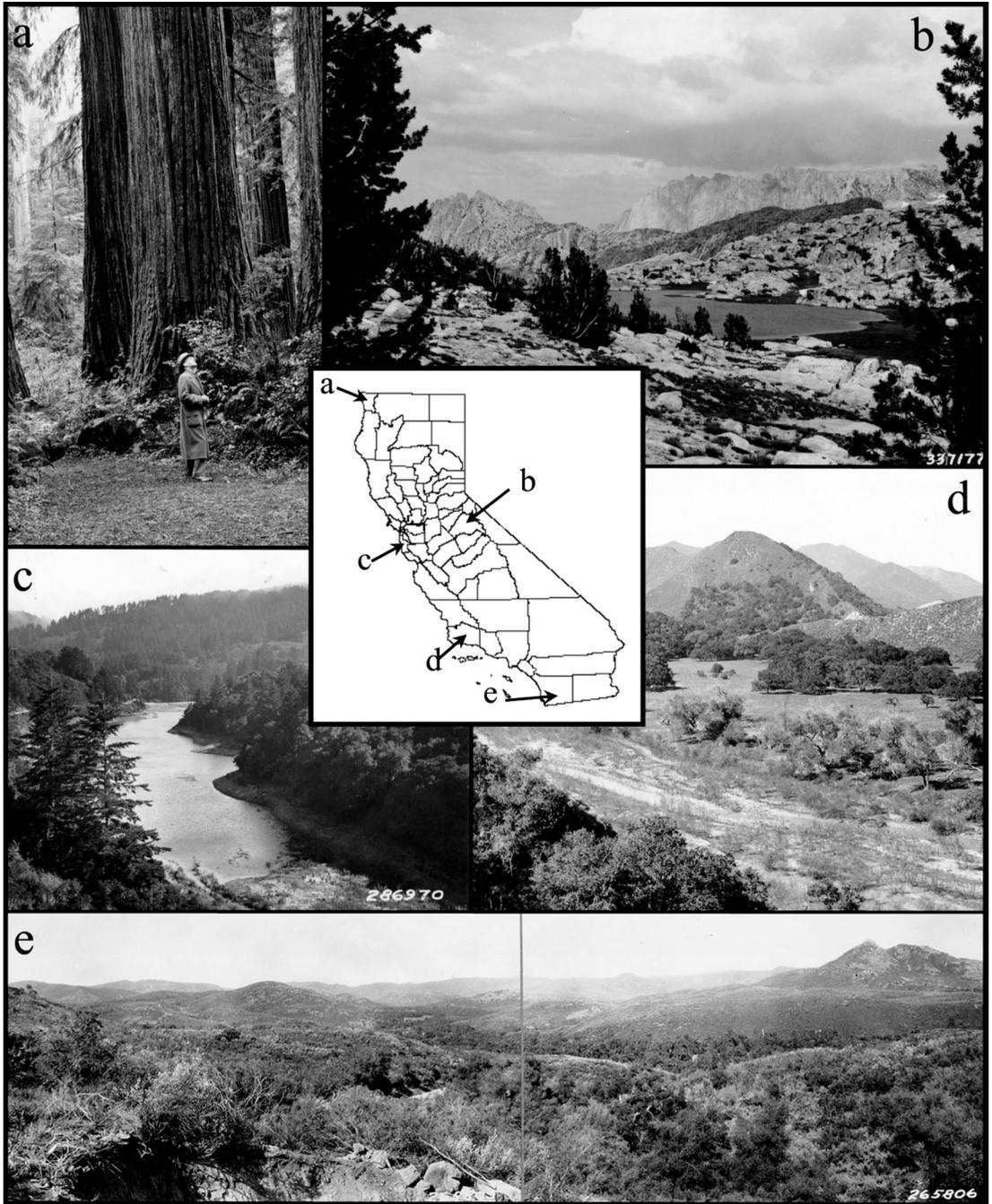
FIG. 3. Representative photographs from the original VTM collection (all photographs taken by A. E. Wieslander, and descriptions from photograph captions): (a) In Mill Creek State Park, Del Norte County, showing coastal redwood and R. D. Garver, taken 11/1/1940; b) Snow Lake in Tuolomne County, showing whitebark pine and associated ground cover, taken 8/1/1936; c) In San Mateo County, showing east arm of Pilarcitos Lake, with Douglas fir, coast live oak, madrone and California bay woodland and coastal sagebrush, taken 7/24/1932; d) Looking southwest down Cuyuma Creek in Santa Barbara County, showing coast live oak woodland and *Salvia leucophylla*; taken 4/5/1936; and e) Panorama looking north and northeast showing Long Valley Peak and Oak Valley in San Diego County, showing coast live oak woodland with scattered Jeffrey pine and Engelmann oak woodland on upper left slope, taken 4/4/1931.

those projects, and others utilizing historic vegetation data.

Plot database. Many researchers have used the VTM collection for research (Bradbury 1974; Minnich et al. 1995; Vayssieres et al. 2000; Franklin et al. 2004; Taylor 2004b), and some of these people have made portions of the VTM plot data digital. Allen-Diaz produced the largest database containing about 4,000 plots, as part of a statewide oak woodland classification effort (Allen et al. 1989). We collected existing electronic versions of VTM plot data and merged them into a standardized database; now we are in the process of entering all remaining plot data into this common database (Fig. 1c). Once completed, each plot will have a unique identifier, based on its quad, the section of the quad, and its unique number in that section. This identifier will geographically locate the plot, and link the plot location with the database for future analysis.

Plot maps. All plot maps have been scanned at 600 dpi, one cut segment at a time. Uncut, scanned versions of each USGS topographic map of the same edition and reprint were searched for in several California map libraries and spatial data clearinghouses. To date, we have found more than half of the maps in an uncut state in either the UCB Map Library, the California State University Chico Meriam Library California Historic Topographic Map Collection, the Los Angeles County Historical Topographic Map Collection, or the map library at the University of California Santa Barbara.

These uncut maps are used in the georeferencing process. Georeferencing is the process whereby a map or set of maps is referenced to true world coordinates through the collection of ''tie points'' (Jensen 1996). The tie points are used to position two images coincident with each other through a geometric transformation that translates the location of each tie point on the historic map to that found on the modern reference map. A root mean squared error (RMSE) is then calculated to estimate overall accuracy of the transformation. Others have attempted this process with the VTM maps. For example, Walker (2000) used modern satellite imagery as the reference map in the georeferencing process. In this case, we first registered the historic uncut maps of the same vintage as the VTM cut maps to modern maps (1:24,000-scale USGS Digital Raster Graphic digital images of modern USGS quadrangles) of a known projection and coordinate system using stable tie points such as roads and peaks. We used between eight and 16 tie points per map. Next, the uncut scanned VTM maps were georeferenced to the georeferenced historic uncut maps using common map features as the tie points. We used a minimum of six tie points per segment. We used first order polynomial transformations for each step. All georeferencing used Erdas Imagine 8.7 software (Leica 2004), and ArcGIS software

(ESRI 2004). Average RMSE for the process was around 60 m. We have performed some preliminary examination of this error, and our results suggest that age of base map is one critical factor in determining error contribution; basemaps made before 1911 have larger RMSE values; and a second important contribution is elevation: maps on lower elevations have less RMSE.

Vegetation maps. The vegetation maps are also being scanned and georeferenced using the same protocol as the plot maps. The vegetation maps have not all been cut into sections, and can be scanned and georeferenced in their entirety. Associated metadata from each vegetation map is collected at the time of scanning. This component of the project is being completed by Jim Thorne and Jeff Kennedy at UCD.

Photograph collection. The Library Photographic Services is digitizing the photograph collection. Each photograph is scanned, and information from its captions has been entered into an Access database, which will be available on the Library Web. Once the project is complete, users will be able to search by keyword, genus and species, and quad name. Data from the caption include a brief description of the location and subject of the photograph including relevant genus and species, and quad name. The photographer, date of the photograph, and occasionally township and range are included. In addition, researchers will be able to search for the photographs using the webGIS tool described below.

Website development. We have developed a website to update interested parties on our progress. The website is currently available at: http://vtm.berkeley.edu/. Here you can find program progress, inventory maps and other information, including our ''webGIS'' application that unites all aspects of the project. WebGIS is a new term that refers to websites that unite two components: (1) GIS database storage and maintenance and (2) Internet accessibility. Although not yet widely used in natural resource management, such systems are a promising option for entering and storing heterogeneous datasets, indexed by location, and making them widely available in a visual, dynamic and interactive format (Kearns et al. 2003). When finished, the website will allow users to view all data associated with the project in mapped form. Users will be able to turn on and off different ''layers'' of data (e.g., modern vegetation, elevation, or VTM plot map quads), zoom in and out, viewing increasing detail as they zoom in, search for particular areas of interest by entering quad name information, or geographic coordinates, view photographs tied to the location, query the plot database, create their own maps, and finally, request the data itself for research purposes.

Figure 4 shows plot maps, and plot locations overlayed on modern topographical data. Once the en-
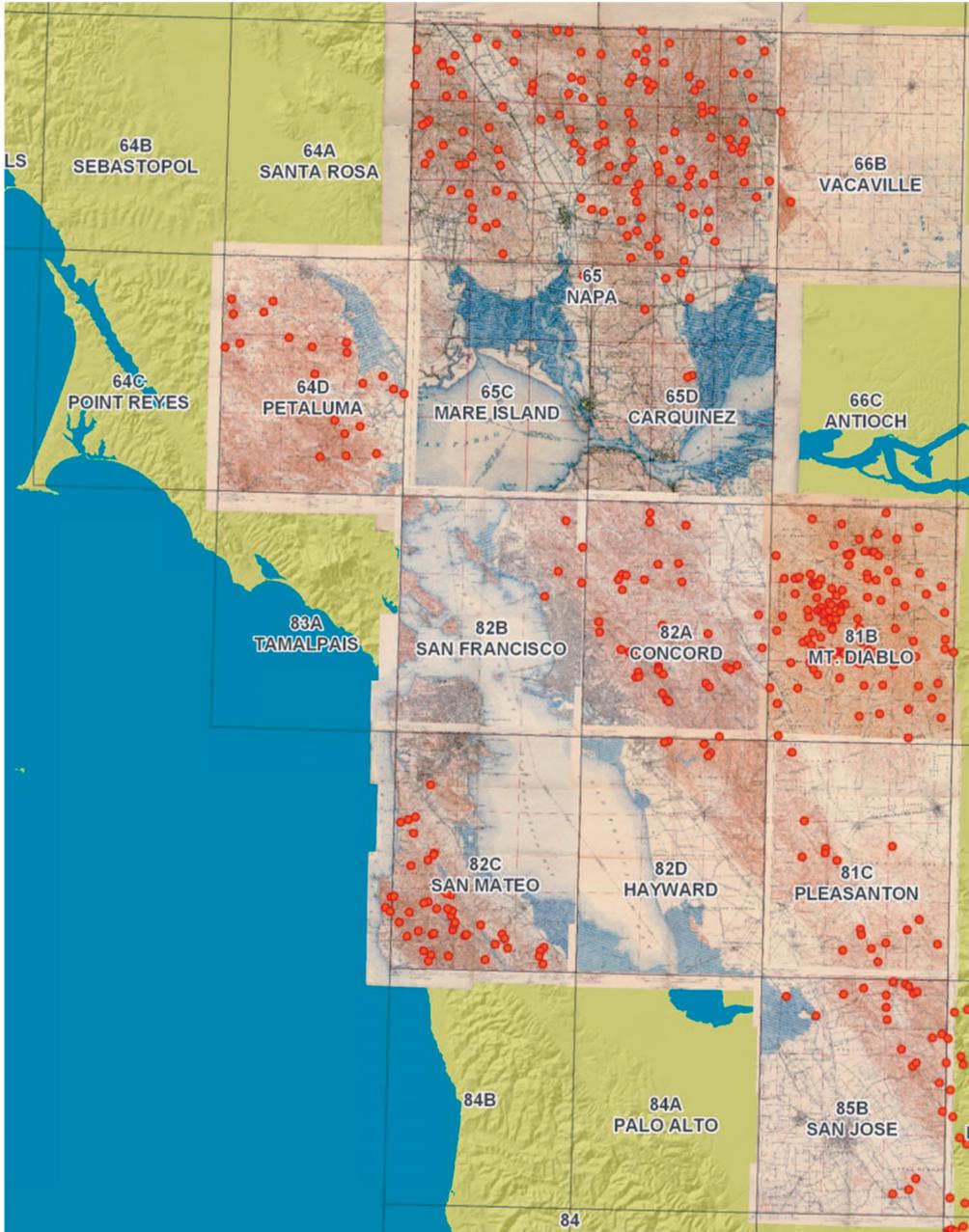
FIG. 4.   VTM plots in the San Francisco Bay area. The original, scanned and georeferenced plot maps from the VTM collection are superimposed on a modern elevation map. Red circles depict locations of VTM plots.

tire collection has been digitized, we will be able to provide this kind of seamless digital view for the entire collection.

DISCUSSION

Potential Users and Uses of the Data

There are many potential users and uses for the data in this collection. Wieslander spent consider-

able time thinking about the uses of these data in the future; and claimed that ''the data not only serve as a basis for mapping sites in the field but also are suitable for scientific study later'' (Wieslander 1935a). He outlined some potential uses for the data in Madroño in 1935 that still hold true today. He wrote the data might provide: 1) a partial explanation of the present distribution of vegetation types and dominant species; 2) a better understand-

ing of vegetation changes that have occurred in the past, those now in progress, or those to be expected to occur in the future; 3) further contributions to our knowledge of the values of certain plants and vegetational types as indicators of particular soil and climatic conditions; and 4) suggestions for future investigations and also a foundation for further research. He also provided explanations of change that might be controversial today: ''the most striking and significant of such changes are those representing a progressive deterioration from higher and more valuable to lower and less valuable types of vegetation as a result of such land abuse as destructive logging, accidental and willful summer fires, the practice of annual burning in many foothill and mountain localities, and excessive grazing'' (all quotes from Wieslander [1935b]).

The VTM methods and resulting data lend themselves to modern ecological research, and to date the data have been used in three broad areas of inquiry. First, the data have been used to classify vegetation communities in the state (Jensen 1947; Griffin and Critchfield 1972; Allen et al. 1989; Allen et al. 1991; Allen-Diaz and Holzman 1991). The detailed collection and recording of floristic and environmental detail at the plot scale allows for *a posteriori* determination of vegetation types by researchers (Walker 2000), making the data more useable and flexible for modern ecologists. This approach was used by Allen-Diaz et al. (1989) in creating a comprehensive classification scheme for California's hardwood rangelands, which in turn was used in the manual of California Vegetation (Sawyer and Keeler-Wolf 1995). The data have also been used to validate modern models of vegetation composition (Vayssieres et al. 2000; Franklin 2002). These efforts assume a static vegetation composition over decades at a large scale (e.g., Franklin (2002) examined a 3880 km² study area).

Secondly, the decades-old collection of plot data has also been used in reconstructing California vegetation conditions in the early 20th century in order to examine changes due to disturbances such as fire and disease, or to examine local trajectories of land cover change. Bradbury (1974) was perhaps the earliest published example of this. He examined 40 years of change in San Diego County vegetation, and found little change in the area, most of which was clearly disturbance-related (Bradbury 1974; Franklin 2002). In contrast, other researchers found significant changes in species composition. For example, Minnich et al. (1995) used VTM data to document significant shifts in species composition and stand density in the San Bernardino Mountains of California, and discussed the role of fire in changing the forests in California conifer forests. Taylor (2004) relocated 78 VTM plots in San Diego County, and discovered that while overall shrub cover loss was less than reported in a comparable area (Riverside County), there was a shift in composition in several shrub communities in the San

Diego County area (Taylor 2004b). These studies that relocate VTM plot data and compare plant abundance and distribution measures with current data might be more successful in certain vegetation types; for example, areas with trees or with less diversity might be more amenable to comparative analyses. Efforts over larger scales also should be encouraged, as successful relocation of individual plots can be problematic (Keeley 2004).

Finally, the vegetation map portion of the VTM collection has also been put to use. Walker (2000) compared the VTM vegetation maps and other historic sources of vegetation distribution in Yosemite National Park with modern sources of mapped vegetation data to examine decadal changes across the Park. Such retrospective mapping projects are not without challenges: the original inclination of the VTM design was forestry-based, with a vegetation classification scheme developed for the project and designed for further forestry applications. In addition, the vegetation mapping was done via remote vantage points. These choices necessarily resulted in large minimum mapping units and a classification scheme based on overstory canopy dominance. Modern ecologist wishing to examine vegetation changes through these maps should be cognizant of these facts. Indeed, these kinds of considerations are also necessary in comparing different contemporary vegetation datasets (e.g., Manual of California Vegetation Classification and the USFS's CalVeg dataset (Thorne et al. 2004).

We are interested in using the collection to compare current stand structure and composition with 70–80-year-old stand structure in areas affected by the new forest disease called ''Sudden Oak Death'' (Rizzo and Garbelotto 2003). We hope to understand why there is such a patchy distribution of infection in forests with Sudden Oak Death. We intend to look at interrelationships between land use changes, climate changes, pest invasions, stand growth, and infection, and model change in plant community composition and structure. This project is one example of a multi-scaled approach to historical ecology: it utilizes plot level information on current vegetation community structure across a gradient of sites with infected trees, and historical vegetation data at a larger-scale to examine possible explanations for the patchiness of the disease statewide.

Spatial Accuracy Considerations

Re-locating plots from historic maps is recognized by many to be a challenge (for some the greatest challenge) facing modern ecologists using these data. Several researchers have discussed caveats associated with use of historical ecological data, and recommended caution in using older collections. Indeed, the use of PLS data for historical ecology has been controversial because of possible inconsistencies caused by surveyor variability (Gal-

atowitsch 1990). While Schulte and Mladenoff (2001) and Siccama (1971) found that surveyors were consistent in recording distance and direction to witness trees, they also note that surveyors were not consistent in describing species and diameter characteristics, possibly due to seasonality of sampling (Schulte and Mladenoff 2001). In addition, several researchers note variability among surveyors across species, diameter, size and location (Bourdo 1956; Galatowitsch 1990; Manies et al. 2001; Schulte et al. 2002). Overall, however, Manies and Mladenoff (2000) found the PLS method accurately estimated relative species composition and the order of dominance of land cover types at broad spatial scales.

These experiences are applicable to the use of the VTM collection, although surveyor inconsistencies might be less than in the PLS collections as a result of a smaller project, more modern equipment, and perhaps a better-trained staff. Indeed, Minnich et al. (1995) describe confidence in locating plots within a 100 m radius by reference to fixed features such as roads, and the location of prominent trees included in the original dataset (Minnich et al. 1995). In addition, they took three replicates at each plot, to ensure that they had located the plots. Walker (2000) found that while the overall fidelity of species composition mapping was good, the spatial accuracy of the plots (and of vegetation polygons) varied with topography, and spatial error increased in areas of high terrain (Walker 2000). Franklin (2002) found discrepancies between the VTM data and the more modern USFS Forest Inventory and Assessment (FIA) plots over a large area, but proposes that this might be a result of differing sampling schemes between the VTM and FIA plots, not a result of spatial accuracy.

A less optimistic view is presented by Keeley (2004). He found considerable spatial variability in coastal sage scrub and chaparral communities in Southern California. Consequently, he maintains that the accuracy and precision to which VTM plots in chaparral might be relocated is not sufficient to perform plot-by-plot analysis of community change. In other words, when using VTM data on a plot-by-plot basis in chaparral communities, any change found might be an artifact of errors in plot re-location, and not indicative of real change. This is a reasonable argument for chaparral communities, but many authors contend that in forested communities the problem of relocation might not be as severe due to the existence of persistent trees, as described above.

Plot relocation still remains an important challenge in ecological research with these data. We estimate that our georeferencing technique generates plot locations with a combined error of around 200 m on a 15-minute (1:63,500-scale) quad. The plot markings on the original maps constitute the largest component of this error. These plots markers are 3.5 mm in size, generating circles with radii

equivalent to 110 m on the ground when using a 15-minute (1:63,500-scale) map. In addition, the georeferencing process contributes an additional 60 m error (based on the average RMSE for the process, reported in Erdas Imagine). Finally, we need to include the error contributed by the original USGS map itself, which is about 30 m (USGS 1947). We have combined these sources to generate an overall error of about 200 m per plot, which is similar to that reported by Walker (2000) using a different georeferencing method. This amount is in excess of any error in locating the original plot on a quad by the VTM crew in the field. The overall error might be lessened through use of the slope and aspect values recorded in the plot data in comparison with topographic data from a modern Digital Elevation Model (Taylor 2004a).

Conclusions

California's landscape is complex, varied and extremely dynamic, and in the 20th century has experienced numerous agents of large-scale change. Fire, urban and exurban development and expansion, harvesting, invasive species, and new forest diseases such as Sudden Oak Death combine to alter the environment in ways that could not be imagined 80 years ago when Weislander was working. Yet, the legacy that he and his crews have left us, a detailed and accurate picture of California vegetation of that time, help us to understand change, and better manage it for the future. Clearly, the ability to relocate plots with sufficient precision and accuracy for detailed historical analysis will remain an important challenge in historical ecology, but we contend that researchers using historical data have found a range of approaches that address this and make the dataset valuable for ecological research. For example, in areas of little change, the floristic detail of the plot data can support vegetation community classification, or validate new models of species distribution. In areas of change, researchers have pursued landscape and larger scale analysis of historical data, combining several plots and examining changes across watersheds, regions, or even states.

The kind of data repository we are building will provide valuable data and tools for those interested in California's changing vegetation through the 20th century and beyond. We hope to have the data accessible to researchers by Fall 2005 at vtm.berkeley.edu.

and Natural Resources Library at UC Berkeley; and Jeff Kennedy and Jim Thorne from UC Davis. Without all these people, this collection could not have been brought to life again. We are grateful for the insightful comments from three reviewers; incorporation of these reviews greatly strengthened this paper.

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