Dust Deposition in Nevada, California, and Utah, 1984-2002

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Introduction

The U.S. Geological Survey has funded several efforts during the last 20 years to monitor and sample modern dust deposition in the arid southwestern United States. A project to study modern dust deposition relative to soils in southern Nevada and California was initiated in 1984 under the auspices of the Yucca Mountain Site Characterization Project (Interagency Agreement DE-AI08-78ET44802). The dust-deposition project had two initial purposes: (1) to provide data on modern dust composition and deposition rates to a computer model relating soil carbonate to paleoclimate (McFadden and Tinsley, 1985; Mayer and others, 1988); and (2) to provide data on dust deposition rates at specific sites in the southern Great Basin and Mojave Desert where soil chronosequences were studied (McFadden, 1982; Taylor, 1986; Harden and Matti, 1989; Reheis and others, 1989, 1992, 1995; Goodmacher and Rockwell, 1990; Harden and others, 1991) in support of tectonic and stratigraphic investigations for the Yucca Mountain Project. In 1991, new dust trap localities were established in Owens Valley, California, in support of the Desert Winds project of the U.S. Geological Survey. These Owens Valley sites were intended to monitor dust being deflated from the dry bed of Owens Lake, at that time the single largest dust source in the United States (Saint Amand and others, 1986; Cahill and others, 1996; Reheis, 1997; Reheis and others, 2002). Beginning in 1998, dust traps were also established at several Clim-Met stations and nearby sites on the Colorado Plateau, Utah, and on Soda Lake playa, California. These Clim-Met stations monitor meteorological and sediment characteristics at sites selected to illuminate the relations between dust sources, present climate, and land use patterns; results of these studies will be used to help predict the effects of global climate change (Reynolds and others, in press; U.S. Geological Survey and Desert Research Institute, 1999).

The initial 46 sampling sites in southern Nevada and California, including one site with five traps (T1 through T5), were established in 1984 and were supplemented by nine more sites in 1985 to provide dust data to soil studies by other investigators along the Elsinore Fault and in the Transverse Ranges of southern California (Fig. 1). These 55 sites (Table 1; designated as T followed by a number) were sampled annually through 1989 (Reheis and Kihl, 1995; data available online at http://geochange.er.usgs.gov/pub/dust/). Sampling continued at 37 of these sites (in 1989, many sites were increased to two dust traps), plus a new site (T61) every two years until 1999. A subset of 14 of these sites is now being sampled twice a year to provide information on seasonal changes in dust deposition. The dust traps in Owens Valley (T62-T68, Fig. 1) were established in 1991 and sampled twice a year until 1999, and again in 2001-2002. The Clim-Met traps (CM2-CM8) were emplaced at different times from 1998 to 2000; these dust

traps are sampled twice a year, as are an additional four sites in the Colorado Plateau region (CP1-CP4) emplaced in 2001 (Fig. 2).

The purpose of this report is to make available an up-to-date set of laboratory data and dust deposition rates for all these sites. This data set focuses on the physical and chemical properties of the dust samples. Mineralogical and elemental compositions of dust samples from southern Nevada and California have been published or released previously (Reheis and others, 1999, 2002; http://geochange.er.usgs.gov/pub/dust/). Table 1 includes information on locations of all the dust traps and the lithologic composition of nearby dust sources. The remaining Tables 2-4 are subdivided: part A of each numbered table reports data for the long-term sites in southern Nevada and California from 1984 to 1999; part B reports seasonal data for the long-term sites still being maintained from 1999 to 2002; part C reports seasonal data for Owens Valley sites from 1991 to 2002; and part D reports seasonal data for the Clim-Met sites and associated localities on the Colorado Plateau and near Soda Lake. Table 2 provides descriptive information on conditions, problems, site modifications, and number of accumulation days for each sample. Table 3 provides laboratory data for each sample. Table 4 provides dust deposition data; in this table, parts B, C, and D are subdivided to show annual rates in subpart 1 and seasonal daily rates in subpart 2.

Location and construction of dust traps

The sampling design for these dust studies was based on the need to provide data on dust deposition at soil-study sites and to answer specific questions about the relations of dust to local source lithology and type, distance from source, climate, and local land use practices (Table 1). Some sites were chosen for their proximity to potential dust sources of different lithologic composition (for example, playas versus granitic, calcic, or mafic alluvial fans). Other sites were placed along transects crossing topographic barriers downwind from a dust source (Reheis and Kihl, 1995). In addition, some sites were chosen for their proximity to weather stations.

Four dust traps are located within the narrowest part of Owens Valley on a transect southward from the south end of Owens (dry) Lake; previous research has shown that many of the large storms transport dust to the south (Reid and others, 1994). One of these sites, T65, was vandalized in 1995 and was subsequently abandoned. Three traps are located north of Owens (dry) Lake to assess dust deposition on opposite sides of Owens Valley and on the crest of the White Mountains.

The Clim-Met stations and associated dust traps (CM2-CM8, CP1-CP4) were established to investigate differing effects of land use and geomorphic setting on wind erosion and dust deposition. CM2, CM3, CM4, and CM8 as well as the CP traps are in or near Canyonlands National Park, whereas CM5, CM6, and CM7 are located at sites around Soda Lake in the Mojave Desert where active dust emission has been observed.

Specific locations for dust traps were chosen on the basis of the above criteria plus accessibility, absence of dirt roads or other artificially disturbed areas upwind, and inconspicuousness. The last factor is important because most of the sites are not protected or regularly monitored; hence, most sites are at least 0.5 mile from a road or trail. Despite these

precautions, dust traps are sometimes tampered with. This is a particular problem in areas close to population centers such as Los Angeles and Las Vegas. Dust traps were also generally placed in flat, relatively open areas to mitigate wind-eddy effects created by tall vegetation or topographic irregularities.

Sites far from human presence are scarce in Owens Valley because this narrow valley is a communication corridor, containing a major highway, parallel dirt roads, large power lines, and the Los Angeles Aqueduct and its supporting roads. As a result, sites south of Owens (dry) Lake are mostly situated 0.5-1 km east of the main path of dust storms.

For details on dust-trap construction and collection techniques, see Reheis and Kihl (1995) and Reheis (1997). Briefly, the trap consists of a coated angel-food cake pan painted black on the outside and mounted on a post about 2 m above the ground (see photographs in Fig. 2 of Reheis, 1999). Glass marbles rest on a circular piece of metal mesh (initially, galvanized hardware cloth; replaced on all dust traps by stainless-steel mesh in 1999) that is fitted into the pan so that it rests 3-4 cm below the rim. The 2-m height eliminates most saltating sand-sized particles. The marbles simulate the effect of a gravelly surface and prevent dust that has filtered or washed into the bottom of the pan from being blown away. The dust traps are fitted with two metal straps looped in an inverted basket shape and the top surfaces of the straps are coated with a sticky material that effectively discourages birds from roosting. In some localities (notably sites T10, T35, T36, T39, T43, T44, T46, and T61) where grazing animals scratched themselves on the fence posts, the pans were commonly fitted with a top layer of mesh to prevent the marbles from flying out.

Extra dust traps surrounded by alter-type wind baffles were constructed in 1986 at four sites in southern Nevada and California characterized by different plant communities. These communities and sites are: blackbrush (*Coleogyne ramosissima*), creosote bush (*Larrea divaricata*), and other low brushy plants at site T3 on Fortymile Wash; Joshua tree (*Yucca brevifolia*), other tall yucca species, and blackbrush at site T18A on the Kyle Canyon fan; pinyon-juniper (*Pinus monophylla-Juniperus* sp) at site T7A on Pahute Mesa; and acacia (*acacia* sp), creosote bush, and blackbrush at site T26A near the McCoy Mountains. The wind baffles imitate the effect of ground-level wind speed at the 2-m height of the dust trap and permit comparison of the amount of dust caught by an unshielded trap with the amount that should be caught at ground level where vegetation breaks the wind.

Sampling and Analysis

Samples are obtained from the dust traps by carefully washing the marbles, screen, and pan with distilled water into plastic 1-liter bottles (Table 2). Samples have been taken at different intervals, as described above: annual, biannual, and semiannual (the latter is current practice). Semiannual sampling is intended to evaluate seasonal differences in dust transport and deposition. “Winter” samples accumulate from about November through April; “summer” samples accumulate from about May through October (actual sampling dates vary depending on field work schedules). In the Mojave Desert, the dustiest season is usually winter and especially early spring, whereas dust deposition tends to be higher in the summer on the Colorado Plateau.

From 1985 through 1995, laboratory analyses were performed at the Institute of Arctic and Alpine Research in Boulder, Colorado, using standard laboratory techniques for soil samples (Fig. 3; Jackson, 1958; Black, 1965; Singer and Janitzky, 1986) that we adapted for use on very small samples (a dust sample collected from one trap typically weighs less than 1 g). These adaptations generally resulted in larger standard errors than normal for the results of different techniques because the amount of sample used was smaller than the recommended amount. Since 1995, the work has been performed in the Sediment Laboratory of the U.S. Geological Survey, Earth Surface Processes Team, in Denver, Colorado. This change coincided with the advent of new laboratory equipment and techniques better suited to small samples (Fig. 3), including coulometric analysis of total carbon and inorganic carbon (Engleman and others, 1985) and laser particle-size analysis (McCave and Syvitski, 1991).

It is important to note one deviation from standard practices of particle-size analysis. Normally, sediment containing secondary carbonates is treated with a weak solution of HCl or sodium acetate to eliminate the potential flocculating effects of carbonates on clay- and silt-sized particles. The dust samples were too small to be so treated prior to 1997, when particle size was measured by pipette or Sedigraph (soluble salts and organic matter were removed). When the laser technique was adopted after 1997, I opted to keep the methods the same so that the data from all years would be directly comparable. Thus, it is possible that the particle-size distribution may be somewhat coarser than if carbonates had been removed (i.e., some clay particles may have been measured as fine silt, or fine silt as medium or coarse silt).

In the laboratory, the sample is slowly dried at about 35°C in large evaporating dishes or beakers; coarse organic material is removed during this process. Subsequent physical and chemical analyses on dust samples include (1) moisture, (2) organic matter, (3) soluble salts (4) total carbonate (calcite plus dolomite), and (5) grain size (Table 3 and Fig. 3). Other chemical analyses such as phosphorus fractions, strontium and other isotopes, elemental and mineralogical composition, and magnetic properties are performed on selected samples depending on sample size and research needs. The database for any one site commonly contains gaps depending on how far the sample for a particular year could be stretched through the analytical cascade. In some cases, samples from different years at the same site or adjacent sites were combined to obtain enough material for measuring grain size (Table 3). A sample is commonly retrieved and used in more than one analysis if the first analytical procedure used is non-destructive.

Calculations of Dust Flux

Total dust flux ($g/cm^2/yr$; Table 4) is calculated using the following equation, which excludes particles larger than sand-sized:

$$W * 1/A * F/100 * 365/D * 1/P$$

where W = mineral weight (excluding organics) in grams, A = area of pan in cm^2, F = <2 mm fraction in percent, D = number of days out, and P = number of pans at site. Salt flux and gypsum flux are calculated by multiplying the total dust flux by the percentage of salt or gypsum. Dust-flux values for grain-size categories are calculated similarly, except that the percentages of these components were measured on samples after soluble salt and gypsum were

removed (Fig. 3); thus, these calculations are adjusted to a salt-free basis. Dust-flux values for carbonate were calculated like those for grain size categories from 1985 to 1995. After that time, carbonate percentage was measured on a split of the total sample using a coulometer (Fig. 3), so carbonate fluxes after 1995 are not adjusted to a salt-free basis.

Because the seasonal sampling intervals varied from year to year depending on the field schedule, annual dust flux could not be directly calculated by adding the fluxes from winter and summer samples. Hence, annual flux (g/m^2/year) is extrapolated by multiplying the winter and summer daily fluxes of one year by 182.5 and adding the two resulting seasonal fluxes.

Examination of data indicated that samples from some sites collected in 1985 and 1986, before the trap design was modified to discourage birds from roosting, were anomalously large (50-500% greater) compared to those collected in later years (Table 4). All of the anomalous samples were noted at the time of collection to have significant amounts of bird feces (Table 2; Fig. 2 in Reheis, 1999). Guano contains abundant calcium phosphate. Drees and others (1993) showed that high concentrations of water-soluble K in dust samples from West Africa were caused by bird urine. Consultations with ornithologists confirmed that guano can contain significant amounts of mineral matter, mostly derived from cropstones; the amount varies with the species and with the diet of local populations of individual species. Moreover, perching birds can contaminate the sample with material from their feet. In some cases, I have evidence of near-deliberate contamination in the form of one or two pebble-sized clasts of local rocks that were found in samples, possibly dropped (or swapped for marbles) by large birds such as ravens (Table 2). Data from samples with large amounts of guano were discarded from further analysis and were excluded from the computations of "selected average" flux values (Table 4).

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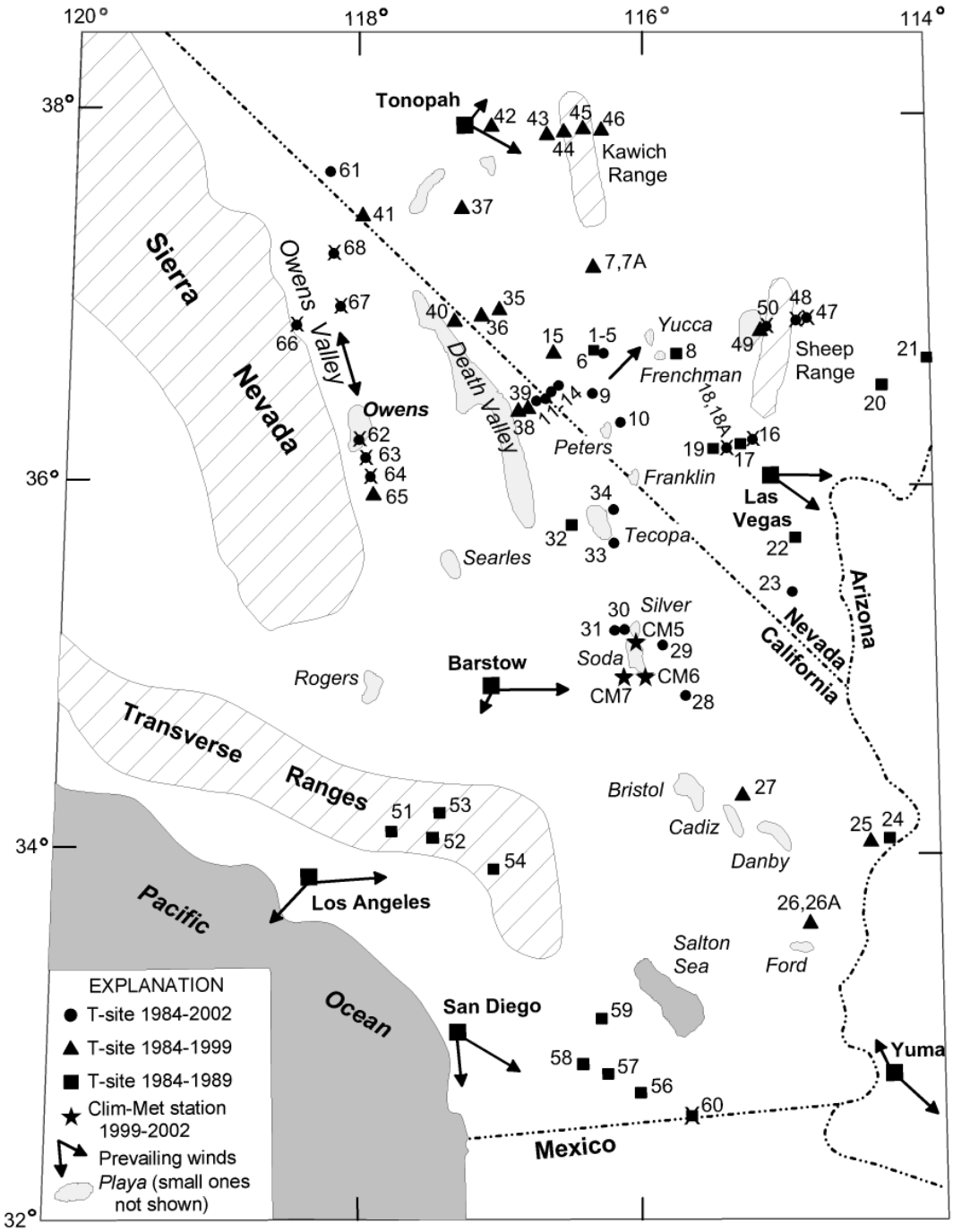

Figure 1. Map of California-Nevada portion of study area showing dust trap sites, dry lake beds, and prevailing winds. Length of arrow is proportional to frequency and strength of annual winds. X through site marker indicates that trap is still in place (as far as presently known) but has been sampled irregularly if at all since the year indicated. Years of sampling are approximate; see Table 1 for actual length of record at each site.

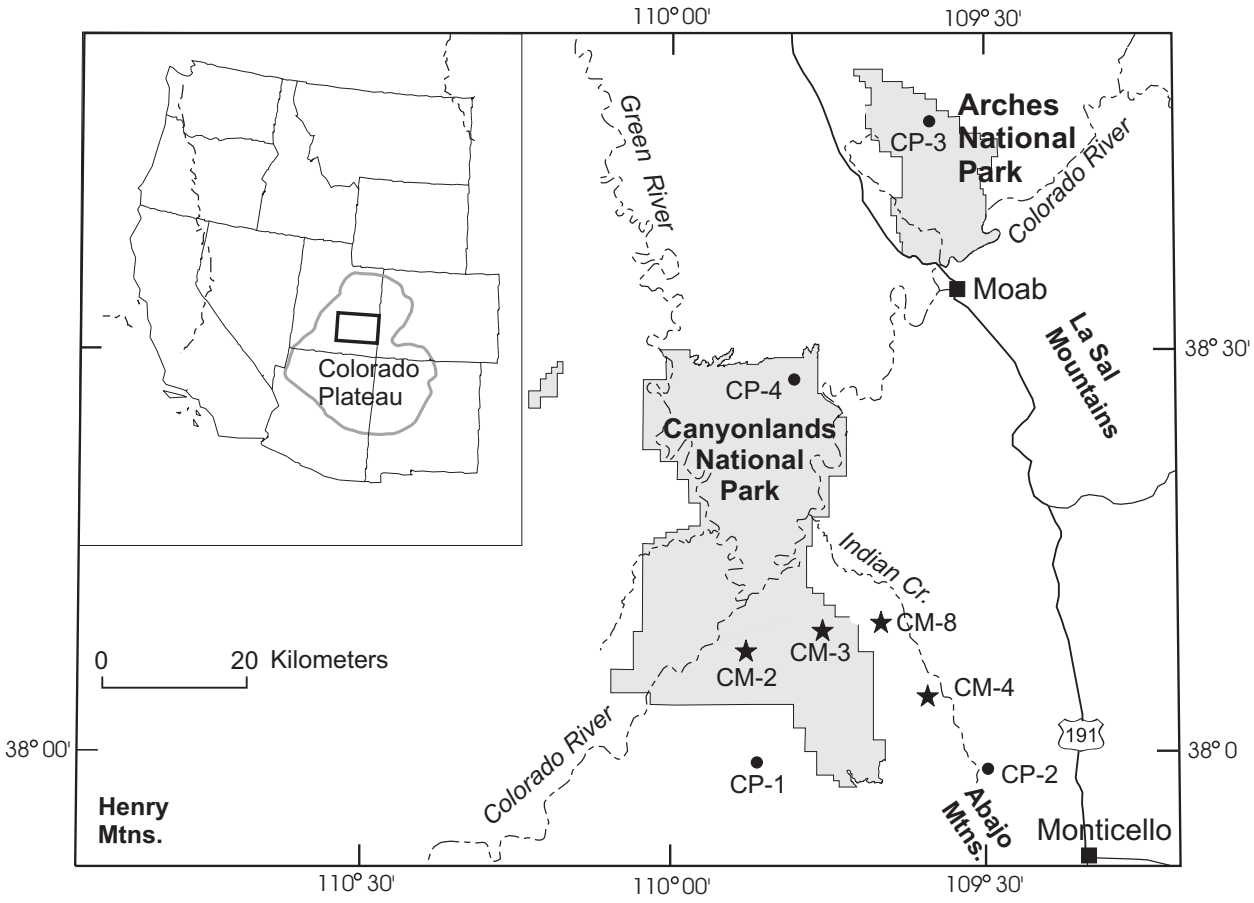

Figure 2. Map of southeastern Utah portion of study area showing dust trap sites and Clim-Met stations.

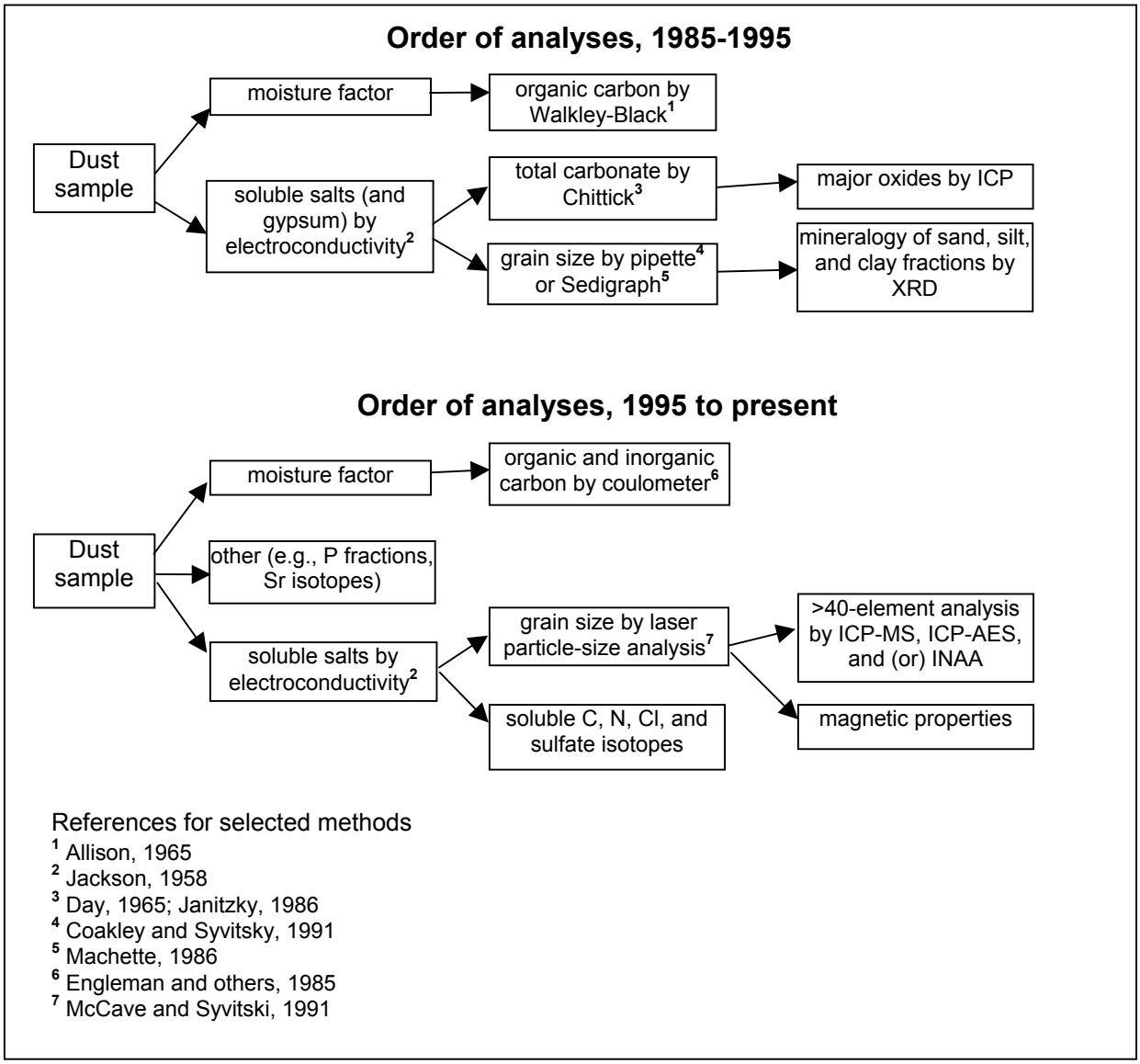

Figure 3. Order and types of analytical procedures followed in dust analyses.