the Pacific (*13, 15*). In a regional study (*2*), I found it to be the dominant species in sediments below the Alaskan Stream and Bering Basin waters, with a sharp cutoff at the continental slope. Assemblage 4 is thus a marker of oceanic waters of higher temperature and salinity than those of the Bering shelf—in particular, the Alaskan Stream and derived waters.

The most abundant diatom species in the sediments are not necessarily those that are most abundant among the plankton (*15*). This difference stems in part from the effect of differential predation by herbivores and in part from the diverse susceptibilities of diatom valves to dissolution. Two of the most common genera of the plankton (*Rhizosolenia* and *Chaetoceros*) are rarely found in the sediments (*15*), probably because of their slight silicification. The assemblages of diatoms in the sediment are thus not representative of the living plankton.

Nevertheless, the assemblages in the sediment appear to be consistent with hydrographic and productivity patterns. This lends support to the hypothesis that diatoms in the sediments can be used to reconstruct details of hydrographic circulation and that fossil diatoms in older sediments may serve as guides to paleohydrography and paleoproductivity. In addition, shifts in the relative abundance of benthic, shallow-water species and pelagic species in cores from the outer continental shelf that contain a record of glacial events may indicate fluctuations in sea level that were due to changes in ice volume. The distribution of Assemblage 2 (ice-dwelling species) may also be used, to a first approximation, to estimate the extent and duration of sea ice during glacial intervals.

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6 June 1980

A Three-Band Hand-Held Radiometer for Field Use

Abstract. *A self-contained, hand-held radiometer designed for field use has been constructed and tested. The 4.5-kilogram device, consisting of a strap-supported electronics module and a hand-held probe containing three sensors, is powered by flashlight and transistor radio batteries, uses two silicon and one lead sulfide detector, has three liquid-crystal displays, features sample-and-hold radiometric sampling, and is spectrally configured to Landsat-D's thematic mapper bands TM3 (0.63 to 0.69 micrometer), TM4 (0.76 to 0.90 micrometer), and TM5 (1.55 to 1.75 micrometers). The device was designed to collect ground-truth data for the thematic mapper and to facilitate ground-based, remote-sensing studies of natural materials in situ. Prototype instruments were extensively tested under laboratory and field conditions, with satisfactory results.*

The applications of remotely sensed data for environmental monitoring have increased substantially since the launch of Landsat-1 in 1972. This new technology has been extended into many disciplines to study various resource questions, and Landsat data have been used in most remote-sensing research to date. However, ground-based remote-sensing studies are needed to better understand the basic relations between natural materials in situ and reflectance or radiance as a function of wavelength. Landsat multispectral scanner imagery is not the best method to use in more fundamental remote-sensing research on natural materials. Considerable difficulties are encountered in sampling ground areas of ~ 0.4 ha, measuring atmospheric variability, compensating for sun angle effects, accounting for instrument responses, and determining the interactions between such sources of variation.

Ground-based spectrometers have been used by several research groups in an attempt to collect spectral reflectance data for natural materials in situ (*1*). These efforts have largely been successful but have also demonstrated some of the limitations of spectrometers: their cumbersomeness, the high cost of maintaining and operating them, and their lack of portability. Spectrometers do provide basic information about natural materials and their reflectances as a function of wavelength. This information is not only important per se but has provided the experimental basis for the development of hand-held radiometers.

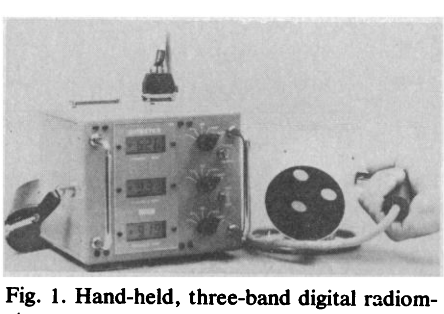

Fig. 1. Hand-held, three-band digital radiometer.

Hand-held radiometers have discrete wave bands and can be carried and operated by one person. Their spectral range is set by placing a filter in the path of each detector. For example, the three-band device described here has two silicon detectors (sensitivity range, ~ 0.4 to 1.1 μm) and one lead sulfide detector (sensitivity range, ~ 1.1 to 3.0 μm). With 0.63- to 0.69-μm and 0.76- to 0.90-μm interference filters placed over the aperture of the silicon channels and a 1.55- to 1.75-μm filter placed over the aperture of the lead sulfide channel, the device responds to the same spectral bands as thematic mapper bands TM3, TM4, and TM5. This device was primarily intended to support Landsat-D's thematic mapper.

A spectral region with a bandwidth of at least 0.04 μm is sensitive to a single property of surfaces with vegetation (*2, 3*). Only Collins (*4*) has indicated that "fine structure" spectral information (< 0.04 μm) may exist for plant canopies. Collins used spectral data collect-

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ed from aircraft, not concurrent or detailed ground-truth sampling.

The existence of broadband (0.04 to 0.20 μm) effects where different properties of surfaces with vegetation can be remotely sensed is advantageous for several reasons: fewer spectral regions have to be measured, which minimizes data rates, data storage, processing time, and the complexity of handling the data; higher signal-to-noise ratios are possible with wider bandwidth systems and thus radiometric accuracy can be improved; and the field of view can be reduced, if needed, without degrading radiometric accuracy.

Recently, others have reported the development and application of hand-held radiometers (*5, 6*). The first such instrument (two-filter) was developed by Birth and McVey (*7*) to measure turf samples. Pearson and Miller (*8*) next developed a two-channel digital radiometer, further described by Pearson *et al.* (*9*). A commercial Landsat radiometer was marketed in 1972 (*10*). Since 1972 the Pearson and Miller (*8*) two-channel instrument has been tested on a variety of vegetation, including grasslands in Colorado (*9*); blue-green algae in hot springs in Yellowstone National Park, Wyoming; arctic tundra in Sweden and alvar on Baltic islands; pastures in Iceland and in England, Scotland, and Wales (*11*); tropical rain forest in Puerto Rico (*12*); and, since 1977, agricultural crops at the Beltsville Agricultural Research Center, Maryland (*13*). The three-band device described here incorporates several new features.

The three-band unit was designed for extended field use by operators with a minimum knowledge of electronics. It is composed of two modules connected by an electrical cable (Fig. 1). The hand-held portion (1 kg) contains one lead sulfide and two silicon detectors with their respective interference filters placed over the collimation tube of each. Optics are not involved other than in the mechanical layout of the collimation tube and interference filter. The hand-held portion also contains the detector preamplifiers, a "zero" adjustment of the lead sulfide channel, a "sample-and-hold" switch, and a sturdy handle for holding the unit or mounting it on an extension device.

The lead sulfide channel is not cooled or chopped and is provided with paired detectors to form a bridge to compensate for changes in temperature. Cooling or mechanically chopping the lead sulfide channel was found to be unnecessary for a reliable, sturdy, and hand-portable instrument supplied by flashlight and transistor batteries. Field experience has shown that the "drift" that does occur in the lead sulfide channel is slow and easily compensated for by the operator in 5 to 10 seconds.

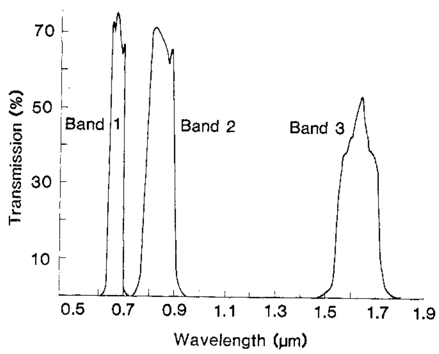

Fig. 2. Spectral acceptance of the radiometer probes. Each probe consists of a silicon or lead sulfide detector that receives signals through a custom-made interference filter.

The outer shell of the hand-held portion is lighttight and is held in place by three screws. The collimation tubes within the shell have a threaded portion that holds the interference filter. The initial spectral configuration closely approximates Landsat-D's thematic mapper bands TM3 (0.63 to 0.69 μm), TM4 (0.76 to 0.90 μm), and TM5 (1.55 to 1.75 μm) (Fig. 2), which are sensitive to the chlorophyll density, green leaf density, and leaf water density, respectively, of a plant canopy (*3*).

The filters can be changed or removed for cleaning by unscrewing the filter-holding apparatus. Interference filters can be custom-ordered from several manufacturers should users desire to obtain a different spectral configuration. The field of view of each collimation tube is ~ 24° (full angle) and can be reduced mechanically by attaching an aperture plate. A cable connects the hand-held portion to the readout module (3.5 kg), which contains the power supply, three liquid-crystal displays, the digitizer and display driver circuits, range controls, battery check, a second sample-and-hold switch, and an on-off switch. The sample-and-hold function can be operated from the readout unit or the sensor unit.

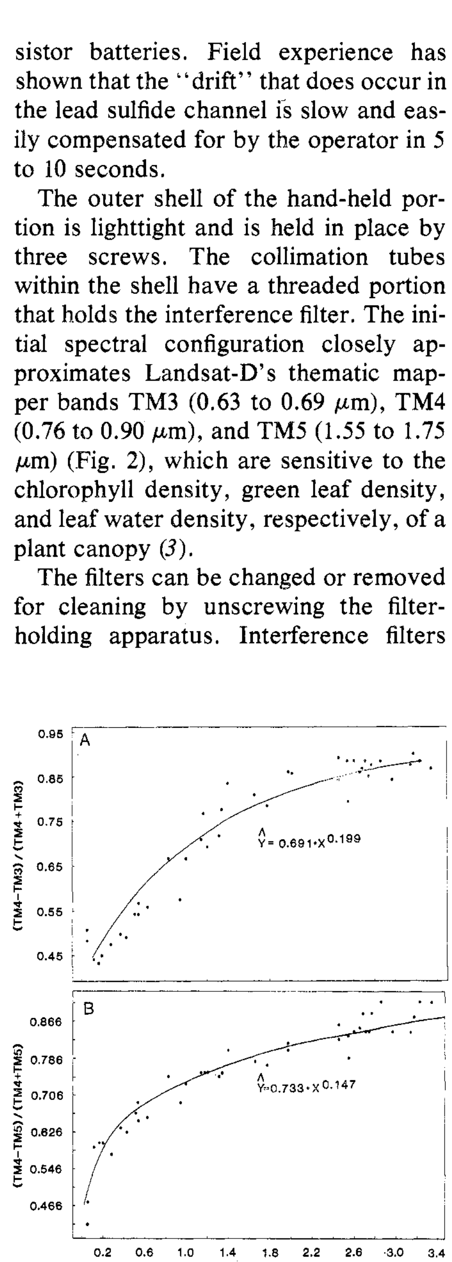

Fig. 3. Normalized difference ratio with (A) TM3 and TM4 bands and (B) TM4 and TM5 bands, both plotted against the green-leaf area index for corn (*6*). The normalized difference was formed in (A) as (TM4 − TM3)/(TM4 + TM3) and in (B) as (TM4 − TM5)/(TM4 + TM5).

There are three liquid-crystal displays with digits 1.25 cm high (one display for each channel). When the sample-and-hold switch is used, all three channel readings are instantaneously held so that the data can be recorded and evaluated. Liquid-crystal displays appear progressively brighter as the sunlight becomes more intense; they are easy to read outside even if one is wearing sunglasses. Each liquid-crystal display comprises three digits with decimal points in radiometric units. Radiometric accuracy is 1 part in 1000 (~ 10 bits), with a total range of 10^6 (20 bits). This translates into a power range of 1 mW/m^2 to 1 kW/m^2 within the optical band-pass. Radiometric sampling occurs four times per second.

Power is provided by four flashlight batteries for the 5-V digital logic and display circuits and by two transistor radio batteries (± 9 V) for the analog circuits. The batteries provide about 100 hours of operating time due to the low power drain of the liquid-crystal displays. The batteries are available from retail stores and are easily changed by removing the bottom panel of the readout unit. In addition, two mercury batteries with a life expectancy of 1 year provide bias for the lead sulfide detector bridge. Complete wiring diagrams and operating instructions are available (*14*).

The readout unit has enough space that a 1000- to 2000-entry digital memory can be added with no modification to the instrument except minor wiring changes. An uncommitted 50-pin connector on the readout case can be used to connect the instrument to external devices. Considerable care was taken to allow for significant modification of the instruments without major changes to the mainframe.

A 4-m extension pole has been built to enable the radiometer user to measure tall crops and plant canopies from the ground (*15*). The device is lightweight and collapsible, accommodates variable row-widths by means of an adjustable crossarm, is counterweighted, and has proved sturdy and stable in field studies of corn (6).

We field-tested three prototype instruments during the 1979 growing season with satisfactory results. The tests were conducted on rangelands in west Texas and on alfalfa, corn, soybeans, and winter wheat at the Beltsville Agricultural Research Center, Maryland. Thirty instruments were tested during the 1980 growing season at locations throughout North America. Some of the collected data appear in Fig. 3.

In addition to the demonstrated uses with vegetation, hand-held radiometers have potential application in any field where radiometric measurements in the 0.3- to 2.5-μm region are of value. The spectral range of the device described in this report may be reset by changing interference filters or detectors.

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11 July 1980

Decipherment of the Earliest Tablets

Abstract. *The first signs of writing were crudely impressed on clay tablets. These signs are found to represent and stand for clay tokens used for recording prior to writing. The recent decoding of a series of tokens makes it possible to identify the signs as units of grain metrology, land measure, animal numeration, and other economic units.*

The recent identification of a system of clay tokens used for recording/counting as a progenitor of writing invites the reevaluation of the earliest written documents, known as tablets (*1*, *2*). This report deals with the first series of tablets which are characterized by crudely impressed signs (Fig. 1). These tablets are usually referred to as "numerical tablets," suggesting that they yield only numerical notations. They will be called here "impressed tablets," and, in light of new evidence drawn from the token system, I will propose a new decipherment of the earliest stages of writing.

The tablets and the signs. About 200 impressed tablets are reported in the literature, coming from excavations in Iran (Susa, Chogha Mish, Godin Tepe, Tepe Sialk, and Tall-i Ghazir), in Iraq (Uruk and Khafaje), and in Syria (Habuba Kabira and Jebel Aruda). They date from about 3150 to 2900 B.C.

Eighteen different signs can be identified on the impressed tablets which, as illustrated in Fig. 2, I interpret as representations of tokens. I view, in particular, the deep circular markings (Fig. 2, columns 1 and 2) as standing for spheres and the shallow circular markings (Fig. 2, column 8) as standing for disks. I equate the short wedges (Fig. 2, columns 9 and 10) with cones and the long wedges (Fig. 2, column 16) with cylinders.

The recent decoding of the meaning of these tokens (*2*) allows me to propose the following decipherment for the tablet in Fig. 1: two "large" measures and three "small" measures of grain (equivalent to about 90 liters of grain). An explanation follows.

The meaning of the wedges, deep circles, and triangles. Jöran Friberg recently documented the fact that the Sumerians and the Elamites used the same system to record grain metrology (*3*, pp. 10 and 20): (i) the most basic unit (about 6 liters of grain), called the *ban* in Sumer, was represented by a wedge; (ii) a unit six times larger, the *bariga*, was represented by a circle; (iii) a fraction of the *ban* was shown as a triangle. I postulate that the shapes of the signs used for grain metrology derive from the tokens in the shape of cones, spheres, and triangles. As a consequence, I consider the small cone to represent the most basic unit of grain. Its shape may be viewed as deriving from the representation of a deep bowl. The sphere will stand, accordingly, for the second most basic unit of grain, of larger size. Its shape may be suggestive of a bag of grain. Large cones and spheres represent still larger units of grain metrology, whereas the plain triangle stands for a fraction of the basic unit.

Fig. 1. Impressed tablet (Gd 73.292) from Godin Tepe, Iran. [Courtesy T. Cuyler Young, Jr., Royal Ontario Museum, Toronto, Canada]

The impression of these tokens on the tablets had the same meaning as the tokens themselves, and, as a consequence, the two small circular impressions and the three wedges on the tablet in Fig. 1 may be read "two 'large' and three 'small' measures of grain." Land measures in Sumer were calculated in terms of the seed ratio necessary for sowing (*4*). It is, therefore, not surprising to find in Friberg that the cones and spheres were also used as units for land measurements (*3*, p. 46). In this case the multiples of the standard Sumerian units, the *iku* (3258 m2) and the *bur* (63504 m2), were expressed by punched cones (Fig. 2, column 11) and spheres (Fig. 2, column 4) and a fraction by an incised sphere (Fig. 2, column 3).

When, how, and why certain signs specifically used for grain and field measurements came to be used for abstract numbers are questions of fundamental importance for the development of mathematics, but they are beyond the scope of this report. In the texts of the Uruk IVa period of 3100 B.C., pictographs in the form of an ear of barley and of a schematized field are added next to the impressed signs in accounts dealing with barley and land to specify that the quantities referred to these commodities, thus suggesting that the process of acquisition