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A MOBILE SPECTROGRAPHIC LABORATORY

(Report and 11 figures)

R.H.C. Holman and C.C. Durham

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ABSTRACT

A mobile spectrographic laboratory mounted in a house trailer is described. The laboratory may be hauled by road to a field site and set up to provide spectrographic analyses of geological materials shortly after collection. All instruments are easily removed from the trailer at the end of a field program for installation in a permanent laboratory.

A MOBILE SPECTROGRAPHIC LABORATORY

INTRODUCTION

During the last ten years geochemical work in the Geological Survey of Canada has greatly increased. This growth has been especially rapid in the application of geochemistry to mineral exploration, and several large-scale geochemical surveys based on the chemical analysis of many thousands of samples have been made. For this type of work it has been found advantageous to establish laboratories in the field under the direct control of the project leader. This arrangement allows temporary personnel to be trained in the minimum of time, ensures the immediate availability of results and permits efficient planning of further sampling.

Early geochemical projects of the Geological Survey of Canada were limited to the analysis of a few elements, such as zinc, lead and copper, that could be easily determined by simple colorimetric techniques. But further investigations have shown the need for more extensive analytical work requiring spectrographic techniques. Spectrographs are generally regarded as fragile instruments and are usually installed in permanent laboratories, but the fact that they can be operated successfully in mobile laboratories has been demonstrated in both the U.S.S.R. (Ratsbaum, 1939) and the U.S.A. (Canney, Myers and Ward, 1957).

In 1961 the Geological Survey considered the acquisition of a mobile spectrographic laboratory. Specifications were compiled and construction of the unit was completed in 1962; field tests over the last three years have proven entirely successful. This paper describes the mobile spectrographic laboratory and comments on problems of its design and general operation.

The mobile laboratory was designed to meet the following general requirements:

1. The laboratory should contain all equipment needed for the semi-quantitative or quantitative spectrographic analysis of rocks, soils and stream sediments.
2. It should be mobile for easy location near a chosen field area.
3. It should be independent, as far as practical, from external services.
4. There should be sufficient working height and floor space to allow a crew of at least three men to maintain a high daily output of analyses.
5. A simple overall design using standard equipment should be used.
6. Spectrographic instrumentation should be, as nearly as possible, of standard design and be easily removed from the mobile laboratory for use in a permanent laboratory at headquarters.

The relative advantages of several different vehicles to house the laboratory were considered. Truck mounting similar to that adopted by the United States Geological Survey and described by Canney, Myers and Ward (1957) has many excellent features such as low cost, extreme ruggedness and mobility, but the disadvantage of a relatively small working area of approximately 7 feet by 12 feet. Larger trucks such as furniture removal vans and small tractor trailers are costly and could not be utilized for general transport at the field site. Large transportable containers of the type that are often used as semi-permanent telephone exchanges and recording stations, are relatively cheap but are not moved easily at short notice. Medium size house trailers were also considered and these were found to meet the most requirements.

Trailer shells of a standard size are relatively cheap and have the added advantage that they can be hauled by a medium-weight truck that can be detached and used in the field area for general purposes. It was calculated that a standard house trailer 24 feet long would provide adequate working space. This could be divided into three compartments, a large central one to house the spectrograph, a medium size one for sample preparation and two smaller ones to serve as a darkroom and a densitometer room. A trailer of this length could be towed without difficulty on all well graded roads and easily manoeuvred into position at the field.

The mobile spectrographic laboratory described in this paper is based on the design of a similar unit built by the United States Geological Survey. The opportunity to inspect that unit and to discuss many problems of design with Dr. F. C. Canney and his colleagues of the United States Geological Survey is gratefully acknowledged.

DESCRIPTION OF THE TRAILER

The shell   The trailer shell is a modified standard house unit 24 feet long, 8 feet wide and 7 feet high. A 6-inch steel "I" beam box frame, with additional "I" beam supports running laterally from the two main longitudinal beams, is mounted on a tandem axle. The construction is a square wooden frame of spruce and fir strengthened externally with lap-jointed 1/4 inch plywood sheeting and covered with 20 gauge aluminum sheeting (Figures 2, 3). The interior of the shell frame is finished with 1/4 inch fir plywood. The ceiling and walls are insulated by 2-inch batts and a plastic vapour barrier, and the floor with 6-inch batts. The windows are of standard design (30 by 15 inches, aluminum-framed, louvred) and fitted with roller blinds and screens. The furniture and equipment are distributed in such a way that the greatest load is carried over the axles; the very heavy weight of the trailer, combined with the heavy duty suspension compensates for the offset of the trailer's centre of gravity.

Furniture   The benches and furniture are mostly of unit construction each module measuring 18 or 24 inches wide, 18 inches deep and 36 inches high (Figure 11). These standardized units allow easy rearrangement of drawers, cupboards and under-bench space when required. The benches are 20 inches wide and finished with black, heavy duty moulded 'Arborite'. Wall cupboards that extend from the ceiling down to the tops of the windows are provided in all rooms (Figures 10, 11).

Layout . The floor area of the trailer is about 190 square feet, and this is divided into a sample preparation room 6 feet by 8 feet, a spectrograph room 11 feet by 8 feet and two rooms each 6 feet by 4 feet for photo processing and densitometry, Figure 1.

Sample preparation room (Figures 10, 11). This is at the rear end of the trailer and is reached from the outside by a door in the rear wall. It contains two benches, giving a total working length of 12 feet, and a small sink. The benches are served with water, gas and electricity from outlets mounted, wherever possible, on the walls to conserve bench space. The sample preparation room and the spectrographic room are interconnected with a sliding door.

Spectrograph room (Figures 7, 8). On one side of this compartment there is a small refrigerator (4 cubic feet capacity), excitation unit and a bench 4 feet long fitted with gas and electricity. Below the bench there are drawers, and a sample storage rack. On the other side of the room is the spectrograph. This is mounted on a portable stand firmly attached by steel bolts to the trailer wall. In one corner, near the arc stand, there is a small cup sink and water outlet for electrode cooling. Waste gases from the arc are exhausted by a fan through a duct in the wall. Several electrical outlets are conveniently situated to provide power for the spectrograph and its accessories. The forward end of the spectrograph room is shaped to follow the contour of the spectrograph and to allow easy access to the darkroom and densitometer room. Double doors, without a centre post, that open to a width of about 46 inches in the trailer wall admit the spectrograph and stand, and allow it to be manoeuvred into position.

Densitometer room (Figure 6). In the densitometer room a reinforced bench 28 inches wide supports the densitometer. A narrow writing bench runs along the side wall. This small room is designed to accommodate one person only working at the densitometer. The densitometer room benches are set at a height of 30 inches, lower than usual, to facilitate viewing the densitometer screen. The densitometer room may be screened from the spectrographic room by a folding fabric door.

Darkroom (Figures 4, 5). The darkroom is fitted with an "L"-shaped stainless steel bench providing 54 inches of working length. There is ample space for loading the spectrograph film holder, and for accommodating a photo-processor and film dryer. There are no windows and light-proofing is simply a matter of caulking seams between partitions where necessary, fitting the door with plastic foam stripping and inserting suitable light baffles in the air vents.

Electrical equipment, power and lighting General lighting is provided by standard fluorescent strip lamps mounted on the ceiling, and on the underside of the wall cupboards. Wall sockets are the standard 110 volt, 15 amp pattern and all circuits are connected to a service box and breaker panel. External power is supplied through a 100 foot length of 100 ampere rubber covered cable. The cable can be connected to any domestic 220 volt single phase service or spliced directly to overhead cables by power company service engineers. All wiring and components are C. S. A. approved and inspected by the Ontario Hydro Commission. Effective grounding is made through a heavy 5-foot spike driven deep into well-watered ground.

A list of electrical equipment with the power requirements is given below.

Electrical equipment

Air conditioner	220 volts,	2,000 watts
Spectrographic source unit	220 volts,	4,000 watts (max.)
Refrigerator	110 volts,	200
Water cooler		350
Water pump		500
Lighting		700
Fans		300
Densitometer		350
Film dryer		1,000
Photo-processor		150
Muffle furnace		1,000
Miscellaneous		1,500
	Total	12,050 watts (max.)

Purchase of an auxiliary electrical generator for the mobile laboratory was considered during the design stage. Engine driven generators of suitable capacity cannot be incorporated satisfactorily into a trailer because of their weight, size, and problems of vibration and noise. In view of these practical difficulties and the fact that all main routes and most rural roads are supplied with power, the purchase of expensive generating equipment for occasional use only was not justified.

Plumbing, water and gas Water is piped to standard laboratory pattern cocks and other outlets in the trailer through $\frac{1}{2}$ inch copper tubing. Water is required mainly for film washing, cooling the photo-processor and spectrographic arc stand and for the two sinks. Hot water is not needed and no water heater was included in the design.

Water can be supplied to the trailer either from a municipal service or by pumping from wells and lakes. A jet-type pump was originally installed but gave trouble with waters containing sediment and has been replaced with a standard 250 gallon per hour piston pump (Figure 3). Water is drawn from a well or lake through a 1-inch plastic pipe and delivered under pressure through a back-flushing filter to a 20 gallon capacity storage tank.

For situations without a nearby source of water, 200 gallons can be stored in four 50 gallon tanks mounted beneath the trailer on the undercarriage. These tanks are designed to carry water only when the trailer is stationary and are drained before moving. It has been found advantageous to keep the water tanks full not only for emergency purposes but also to stabilize the trailer and dampen vibration.

Sinks are drained through plastic pipes and all water circuits are provided with drain cocks for emptying the system before winter storage.

The average water requirements of the trailer are estimated to be about 130 gallons per day. Although shortage of water has not been a problem, it is estimated that the consumption could be reduced to about 60 gallons a day by recirculating water used for cooling the photo-processor and arc stand.

Heating, ventilation and air conditioning The insulation of the trailer shell is adequate for preventing condensation on the walls due to daily changes in temperature but is insufficient protection against prolonged heat or cold. In hot weather a thermostatically-controlled unit mounted on the roof may be switched on. With the doors and windows closed a comfortable working temperature of about 70 degrees can be maintained. A thermostatically-controlled propane heater located in the spectrograph room provides space heating when required (Figure 7). It is usually switched on at night, especially during the spring and fall, to protect the instruments from possible damage by condensation.

The darkroom and densitometer room are ventilated by air drawn from the spectrographic room. With the darkroom door closed, air passes into the densitometer room, enters the darkroom through a light-proof louvre and is discharged into the spectrographic room by an exhaust fan (Figure 7).

Waste gases from the arc are removed by an exhaust fan mounted on the wall immediately above the arc stand (Figure 9).

Storage The exposed spectrographic films are filed in paper envelopes and stored in a nest of small drawers located in the spectrographic room, Figure 8. Unexposed film is kept in the refrigerator until required.

Only the finely-ground powders used for spectrographic analysis are stored in the trailer. Small plastic vials of a standard size are kept in shallow trays supported on racks in the spectrographic room; the specimen trays also fit the standard sample storage cabinets used throughout the Geological Survey.

Ample general storage space is provided by drawers, and wall and floor cupboards throughout the trailer.

SPECTROGRAPHIC EQUIPMENT

The spectrographic equipment carried in the trailer is listed below. Spectrograph - a stigmatic 1.5 m modified Wadsworth wide angle model 78-080; a 15 thousand lines per inch replica grating, blazed for the second order with a linear reciprocal dispersion of 5.4 A. per mm giving a wavelength coverage of 2,100 to 4,300 A. in the second order. The camera photos 20 inches of spectrum, on 35 mm film; the cassette accommodating a 100 foot roll of film. The resolving power is 33,700 and a guaranteed resolution of 0.1 A. A vertical axis and a horizontal axis quartz cylindrical lens projects the source on the collimating mirror. Interchangeable fixed slits of 15, 25 and 40 microns are used. An electromagnetic shutter mounted on the slit body behind the slit proper permits alignment of the discharge image on the slit before the shutter is opened. The film holder is racked vertically from the front of the instrument.

Excitation Unit - Applied Research Laboratories Console; housing interchangeable Low Voltage Spark, Low Voltage Arc and Direct Current Arc Units.

Voltage Regulator - Kelk, Model SM 15T, 230 volts, 18 amp.

Densitometer - Applied Research Laboratories densitometer-comparator model 5400-J.

Voltage Regulator - Sorenson Model 3000S.

Film Processor - Applied Research Laboratories model 2327.

Film Dryer - Applied Research Laboratories model 2352.

Spectrograph This particular spectrograph was chosen for its size and ruggedness. The fixed position optics are ruggedly mounted on a rigid steel plate welded to a sheet steel cover. The adjustment screws on the collimator and grating can easily be locked in position. As mounted at present the instrument measures 85" x 40" x 55" at maximum. The spectrograph is supported by stressed rubber shock absorbers on a heavy wooden stand fitted with castors so that it can be easily moved between the trailer and the permanent laboratory. The instrument is used in its standard form and only the few simple precautions described below are required to protect it from possible damage during transport. Before moving the trailer the arc stand is removed to prevent undue stresses on the optical bench (Figure 9). All moveable light-weight components are immobilized with masking tape. The grating and mirror masks are also taped firmly into position and both optical assemblies carefully sealed against dust with plastic bags and masking tape. The film holder is removed and the camera racking mechanism immobilized by taping it in a central position. The slit housing and camera aperture are also covered with plastic sheeting and sealed with masking tape. As an added precaution against dust, the inspection hatches are sealed with masking tape and the whole instrument covered with a plastic shroud.

Road tests have shown that the shock absorbers adequately protect the spectrograph from mechanical damage during transport. Heavy shocks due to pot-holes in roads are effectively dampened by the slow period of the trailer springing. Lighter vibrations are transmitted quite strongly to the spectrographic stand itself but are entirely absorbed by the rubber mounts and do not reach the spectrograph. As a safety measure the shock mounts are renewed once a year. The spectrograph is not protected against sudden horizontally-directed shocks but these are not likely to occur except by collision or during transport by railroad.

Excitation units During the first two field seasons the mobile laboratory was equipped with a light-weight D. C. current excitation unit with a maximum output of 12 amps

(Figure 9). This unit was perfectly adequate for intermittent use but overheated badly during continuous or frequent use with a corresponding serious drop in output. This unit has now been replaced with the Applied Research Laboratories Console described earlier (Figure 8).

Field tests have shown that fluctuations in the line voltage may occur in rural areas, especially near cottage resorts. Momentary voltage changes also arise from the intermittent use of rock crushers or other heavy equipment connected to the same line. To rectify this problem the spectrographic excitation unit is supplied through a voltage regulator.

Densitometer-comparator (Figure 6). This instrument is permanently mounted on a heavy plywood baseboard so that it can be easily moved between the trailer and the permanent laboratory. In the trailer, the densitometer-comparator is firmly secured by bolting the baseboard directly to the bench in the densitometer room. No special precautions have been found necessary to protect the instrument other than shorting together the galvanometer leads in order to dampen the armature movement. During transport the recording-head housing is clamped firmly with a spring-loaded cloth strap passing over the instrument and attached to the baseboard. A second strap passed horizontally around the base of the instrument prevents the amplifier unit from becoming displaced. The whole instrument is protected from dust by a plastic cover sealed with masking tape.

When used simply as a comparator the instrument is connected directly to the power supply but for photometric measurements requiring a constant voltage, the Sorenson voltage regulator is connected in line.

Photo-processor (Figure 5). This is a robust mechanical unit that requires no special protection against transport shocks. It is mounted directly on the darkroom bench and fixed to the wall with easily removable brackets.

Water cooler To maintain the photo-processor constantly at a temperature of 68 degrees F, a supply of water at about 50 degrees F is required. This is supplied from a standard drinking fountain unit originally located under the darkroom bench. The unit was found to operate adequately under normal conditions but during hot spells, especially when water was drawn from a shallow warm lake, it became overheated and ceased to function. This difficulty has been solved by relocating the cooler outside the trailer over the hitch where it is better ventilated (Figure 3).

Film washer A vertical film washing tank let into the darkroom bench as part of the original design was found to be inefficient, especially when the water supply was limited. This is no longer used and films are now washed with an Applied Research Laboratories trough washer mounted on the darkroom wall (Figure 4).

Film dryer No permanent mounting is provided for the film dryer, and during transport it is simply packed in a cardboard carton.

OPERATION OF THE TRAILER

Haulage The trailer has been towed successfully on flat roads by a standard model C 120 International Travelall fitted with a six cylinder motor, but for hilly country a more suitable gear ratio, or an eight cylinder motor would be an advantage (Figure 2).

A medium-weight 'equalizer' hitch (of the type usually supplied with house trailers) was originally supplied with the trailer but this was found to be inadequate and induced dangerous sway even at a speed of 30 mph. It was replaced with a heavy duty 'Tour-Aid' hitch that has proved entirely satisfactory.

Road tests have shown that tires of light-weight grade are unsuitable for this heavy trailer and are prone to early failure. Eight-ply first quality tires are therefore essential as a safety measure.

Setting-up in the field In the field area a location is found with a nearby power supply and a good source of water. A well-drained site is usually selected away from tracks or roads that may become dusty in dry weather. When possible, the trailer is put in the shade of trees and positioned with the rear door to leeward. Extra protection for the rear door against wind and rain is provided by constructing a canvas porch. The porch also serves as a convenient place to remove heavy outdoor boots and clothing.

Once in position, the trailer is raised from its wheels, supported on concrete blocks, and levelled (Figure 3). Power connections are then made as described earlier and a water line laid to a lake, well or domestic supply. At this stage, and before the instruments are uncovered, the interior of the trailer is thoroughly cleaned with a vacuum cleaner. The spectrograph accessories are then assembled. A check on the alignment of the spectrograph is included in the setting-up routine, but usually little adjustment is required and often it might well be ignored. Setting up the spectrographic laboratory in the field is not a long operation and can usually be completed within one day.

General remarks In general, the design of the mobile spectrographic laboratory has been very successful. The spectrographic equipment, all of standard design, can be removed from the permanent laboratory and readily installed in the trailer and can then be transported by road without damage or suffering serious maladjustment. All equipment functions perfectly under field conditions.

Operation of the unit during several summer seasons has suggested some minor changes in design and equipment and these are being adopted as it becomes convenient. Failure of the water cooling unit in very hot weather has been mentioned and a simple remedy suggested. The Applied Research Laboratories trough-type film washer requires a large intermittent flow of water at low pressure for periods of five minutes, somewhat exceeding the capacity of the pump and storage tank. It is planned to correct this by mounting a separate header tank on the roof of the trailer of sufficient capacity to supply the washer only by gravity.

Personnel Satisfactory operation of the mobile spectrographic laboratory requires the services of a thoroughly competent spectrographic technician who is able to accept the entire responsibility of installing the equipment in the trailer, its transfer to the field, the setting-up of the instruments and the general supervision of seasonal assistants. An ideal crew comprises a technician-in-charge, one graduate student with experience in spectroscopy, and two undergraduate assistants. Duties are rotated, as far as possible, to relieve fatigue from routine but the more exacting work of film reading is usually shared between the technician-in-charge and the graduate assistant.

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1957: A truck-mounted spectrographic laboratory for use in geochemical exploration. Econ. Geol., vol. 52, No. 3, pp. 289-306.

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1939: Field spectroanalytical laboratory for servicing prospecting parties. Razvedka Nedr., vol. 10, No. 1, pp. 38-41. Translated by V. P. Sokoloff in 'Selected Russian Papers on geochemical prospecting for ores' U. S. G. S. pp. 1-6, 1950.

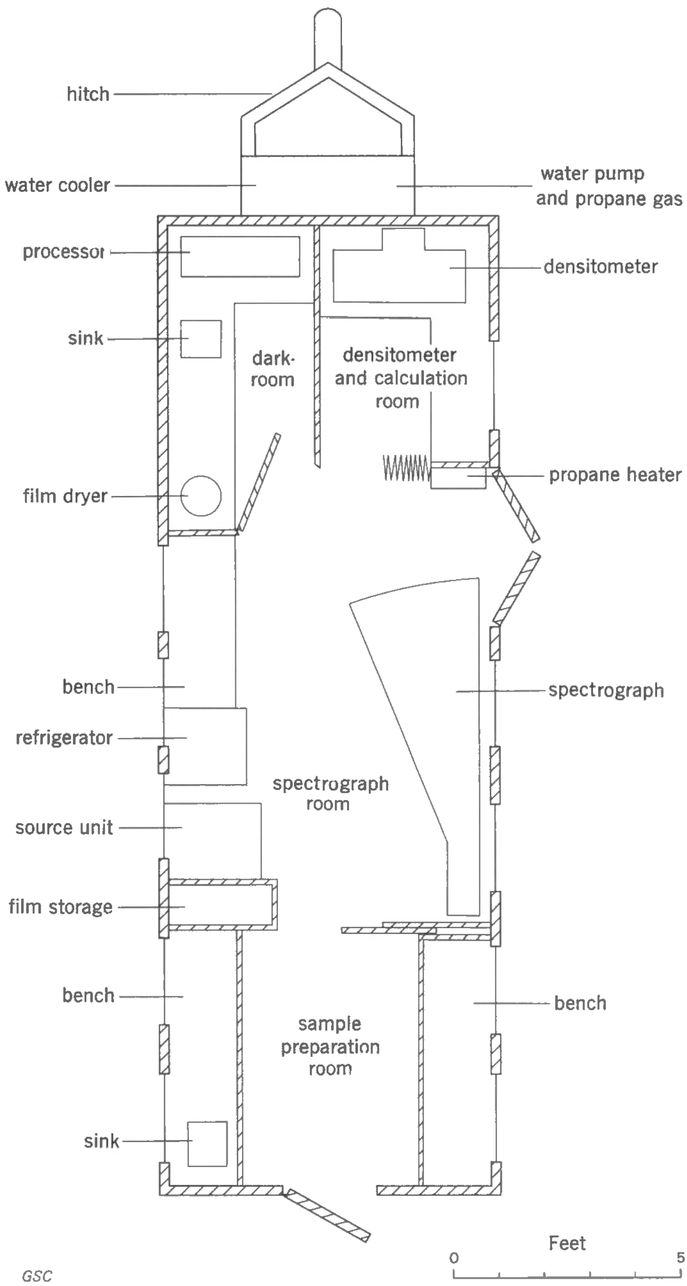


Figure 1. Floor plan of trailer

Figure 2. Trailer and vehicle.

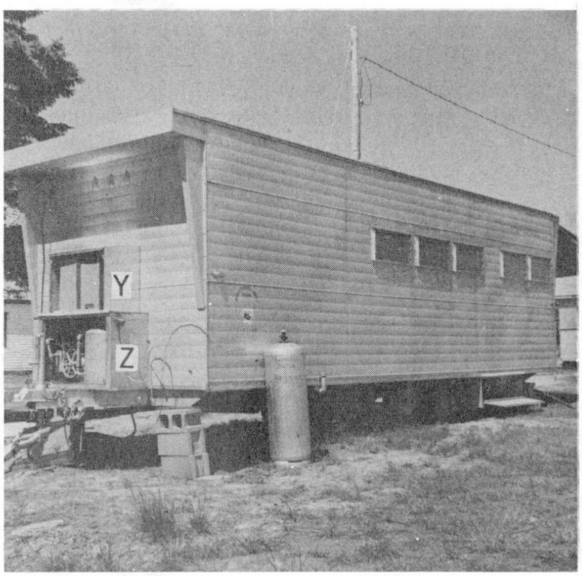
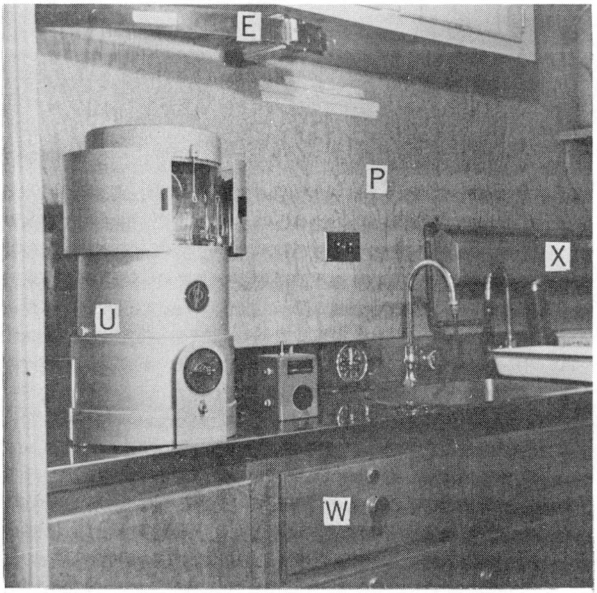


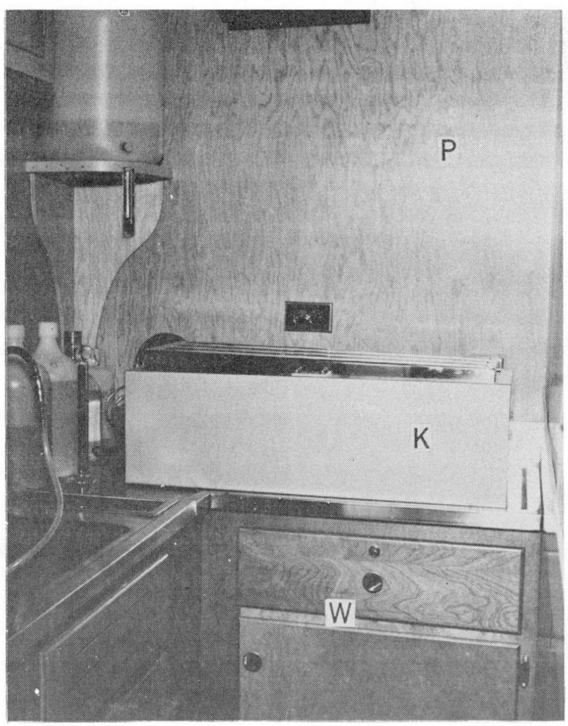
Figure 3. Trailer set-up in field.

Y - water cooler
Z - water pump



E - camera holder
P - darkroom
U - film dryer
X - film washing tank
W - unit construction furniture

Figure 4. Darkroom.



K - photo-processor
P - darkroom
W - unit construction furniture

Figure 5. Darkroom.

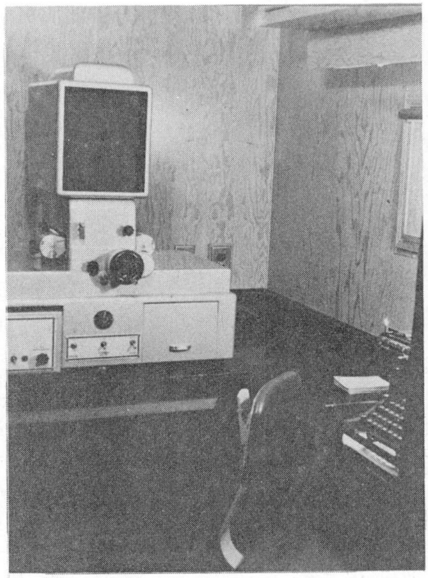
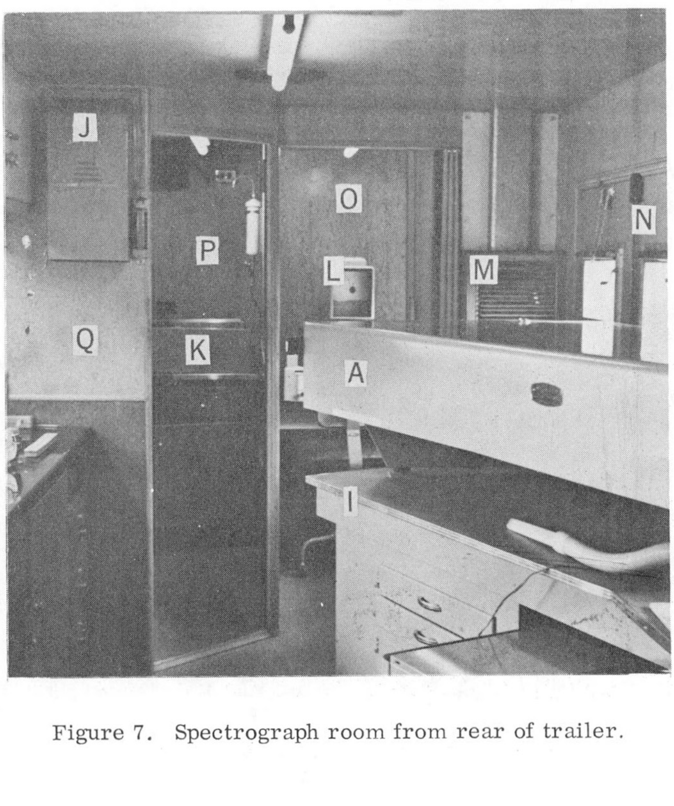
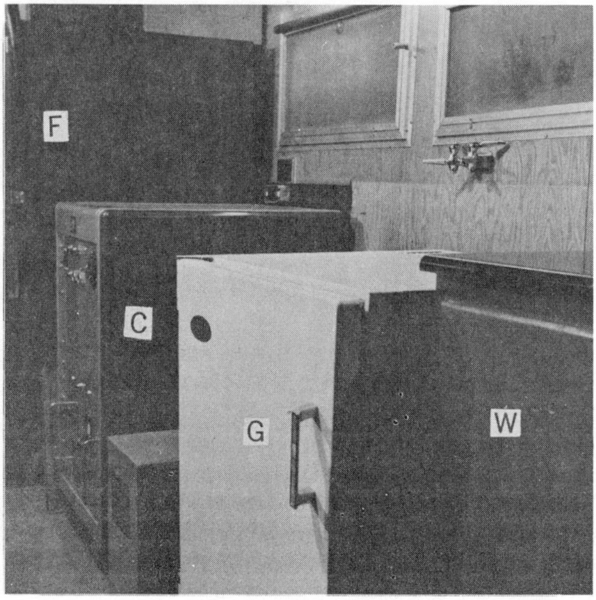


Figure 6. Densitometer room.



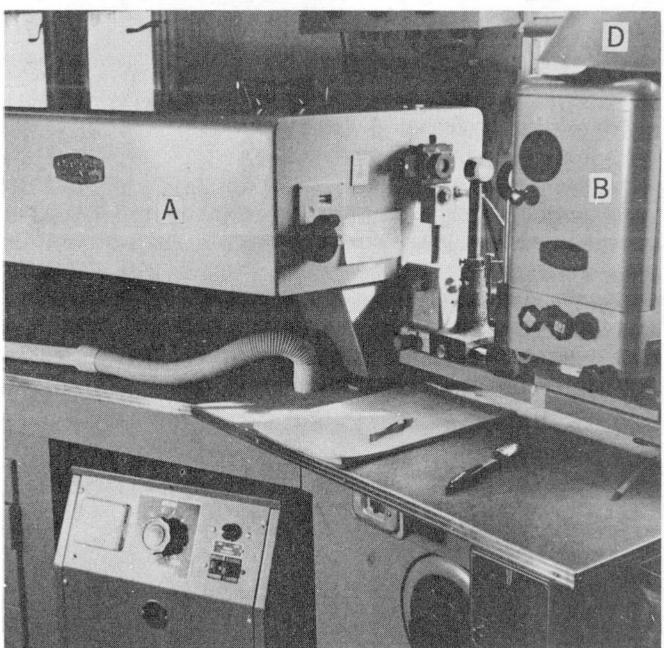
A - spectrograph
I - portable spectrograph stand
J - ventilation fan
K - photo-processor
L - densitometer
M - propane heater
N - double doors
O - densitometer room
P - darkroom
Q - spectograph room

Figure 7. Spectrograph room from rear of trailer.



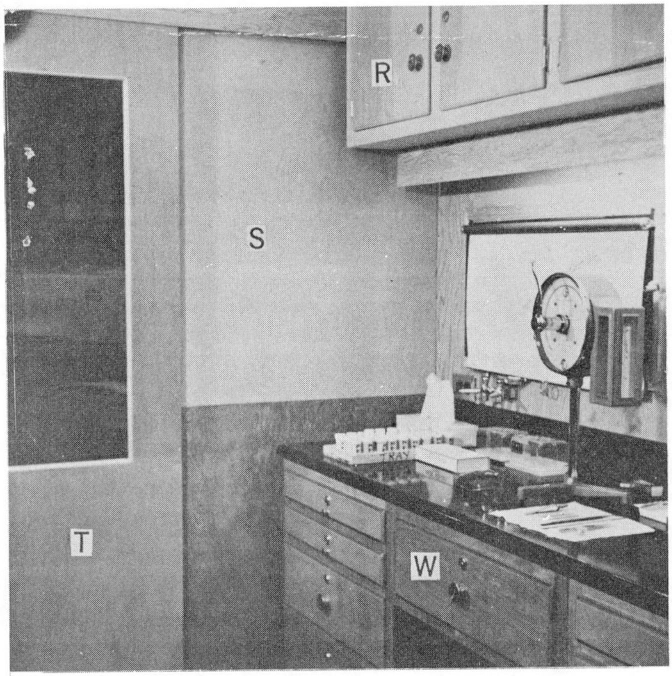
C - D. C. source unit
F - film storage
G - refrigerator
W - unit construction furniture

Figure 8. Spectrograph room.

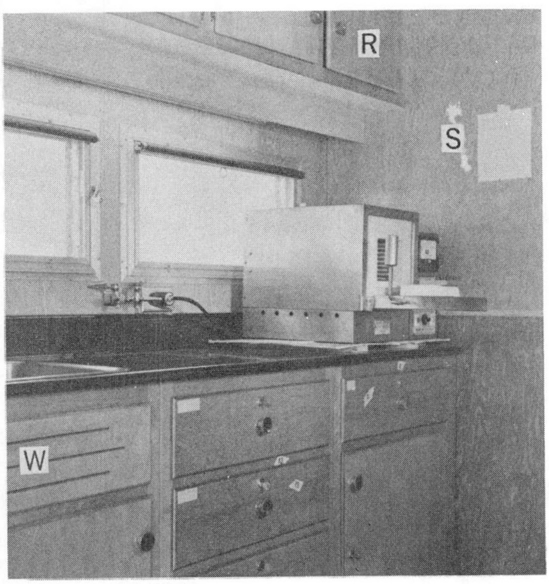


A - spectrograph
B - arc stand
D - exhaust fan

Figure 9. Optical bench of spectrograph.



Figures 10 and 11. Sample preparation room.



R - wall cupboards
S - sample preparation room
T - sliding door
W - unit construction furniture