COMPUTER-ASSISTED MASS SPECTROMETRY AND ITS APPLICATION TO

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RUBIDIUM-STRONTIUM GEOCHRONOLOGY

by

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ABSTRACT

An on-line data acquisition system, centred around an Interdata Model 4 computer, has been designed for a mass spectrometer used primarily for rubidium-strontium geochronology. The digital system has been used for an investigation of the ages of certain gneisses within the southern Omineca Crystalline Belt of British Columbia. With the system, it has proved possible to achieve a precision of 0.02% (95% confidence limit) in the measurement of Sr⁸⁷/Sr⁸⁶ ratios, a precision which was necessary for the investigation described.

The system employs a digital voltmeter at the mass spectrometer for analog-digital conversion of the ion beam. The "conversion complete" signal from the voltmeter is used to interrupt the computer. At each interrupt, the computer reads the mass spectrometer, filters the voltmeter reading, and adjusts the magnet scan speed as required. At the end of each mass spectrum, the data are processed and the isotopic ratios are calculated. They can be output to a digital display at the mass spectrometer as requested by the operator.

Rock samples from the gneisses were obtained from areas near Revelstoke, Quesnel Lake, and Malton Range in order to test suggestions that they represent Precambrian crystalline basement. Samples from the first two locations exhibited a restricted range of Rb/Sr ratios, and required the precise determination of their Sr⁸⁷/Sr⁸⁶ ratios in order to be determined. All areas appear to have experienced an event about

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700 m.yr. ago, and are, therefore, Precambrian in age. The event can possibly be correlated with the East Kootenay Orogeny. In addition, the gneiss at Revelstoke is clearly older than its surrounding metasediments, an observation which supports the thesis of J. V. Ross that it was tectonically emplaced. This latter finding has regional implications in that Precambrian crystalline basement has apparently been involved in the deformation of the region.

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CHAPTER I

INTRODUCTION

I-1 Background

Isotope geophysics studies began at the University of British Columbia in 1960, with the completion of a gas source mass spectrometer which was used to measure the variations in the isotopic composition of lead in ores (Kollar et al., 1960). During the next few years, a major effort of the research group was to improve the measurement of lead isotope ratios by the gas source method (Stacey, 1962; Ostic, 1963; Sinclair, 1964; Weichert, 1965; Small, 1968) and to extend it to materials of low lead concentration (Ulrych, 1962; Whittles, 1964; Reynolds, 1967). Solid source techniques were later introduced to supplement the gas source tetramethylead technique (Ozard, 1970; Hayles, in preparation), and have now replaced it.

During 1962-64, a potassium-argon dating facility was added to the laboratory (White et al., 1967) as a joint project with the Department of Geological Sciences. It has since been used to determine the chronology of different parts of British Columbia. Potassium-argon ages, however, are quite easily affected by subsequent events, and since the province has undergone several orogenies since the late Paleozoic, the ages have in many cases been either partially or totally reset. The earlier geochronologic history of the province has therefore been at least partly obscured. Ages determined by the rubidium-strontium method are not so easily affected by subsequent activity so, in order to look beyond the relatively recent events, it was decided to add a rubidiumstrontium geochronology facility to the laboratory, again with cooperation from the Department of Geological Sciences.

Rubidium-strontium geochronology is based on the β decay of Rb⁸⁷ to Sr⁸⁷, a process which has a half-life of nearly 5 × 10¹⁰ yr. An age determination entails measuring the rubidium and strontium concentrations of a sample in order to determine its Rb/Sr ratio. The isotopic composition of the strontium is also measured, the important ratio being Sr⁸⁷/Sr⁸⁶. An age is normally obtained from a plot of the Rb⁸⁷/Sr⁸⁶ and Sr⁸⁷/Sr⁸⁶ ratios of a group of samples. Under certain conditions the samples will define a straight line, the slope of which is related to the age of the group (Section I-3). Materials dated are either minerals such as biotite or muscovite, or whole rocks.

I-2 Objectives

The two major objectives of this thesis are: 1) to extend the range of problems that can be studied by rubidium-strontium geochronology by improving the precision of the measurement of Sr⁸⁷/Sr⁸⁶ ratios, and

2) to determine whole-rock ages of certain gneisses within the southern part of the Omineca Crystalline Belt of British Columbia in order to ascertain if they are of Precambrian age.

The first objective arose from consideration of some of the limitations of rubidium-strontium geochronology. Since the half-life of Rb⁸⁷ is large, about ten times the age of the earth, radiogenic Sr⁸⁷ accumulates slowly, so that a suite of samples often exhibits a small range in Sr⁸⁷/Sr⁸⁶ ratios. Consequently, the precision of the measurement of this ratio determines the minimum spread in Sr⁸⁷/Sr⁸⁶ ratios a suite of samples must have in order to be dated with acceptable precision. The range in Sr⁸⁷/Sr⁸⁶ ratios is in turn related to the age of the suite, and to the range of Rb/Sr ratios, so that suites with limited variations in Rb/Sr ratios or suites with small ages often cannot be dated. It is apparent that more precise measurement of the Sr⁸⁷/Sr⁸⁶ ratio reduces the range in Sr^{87}/Sr^{86} required, and allows rubidium-strontium geochronology to be applied to a greater variety of problems.

The approach adopted in this thesis has been to improve the precision of Sr⁸⁷/Sr⁸⁶ ratios, to some extent by using improved instrumentation, but largely through the use of more sophisticated data reduction techniques. The improvements in instrumentation included an A.C. filament supply (Russell and Bellis, 1971) and a hybrid solid state measuring system, both designed by R. D. Russell. The data reduction techniques made use of a digital computer, and were a primary responsibility of the writer.

The second objective arose from remarks made by Wheeler (1970) in his summary of a conference on structure

of the southern Canadian Cordillera. In his discussion of future work to be done in the region, he states:

"One of the most important problems concerns whether Precambrian crystalline basement is involved in the deformation of the Eastern Core Zone. Several areas of granitoid gneiss that may possibly represent Precambrian basement have been recognized. These are the Malton gneiss straddling the Rocky Mountain Trench, the gneiss wedge in northern Kootenay Arc, the granitoid gneisses in the cores of Thor-Odin and Frenchman's Cap gneiss domes, and a belt of granitoid gneiss in the western Cariboo Mountains. These areas require detailed and comprehensive radiometric age determination studies by several different methods, especially on zircons from the gneisses, to determine which, if any, are of Precambrian age." (Figure I-1)

Whether Precambrian basement has been involved in the extensive deformation and accompanying metamorphism of southeastern British Columbia is a controversial question. Ross (1968, 1970) has proposed a model for the Paleozoic and Mesozoic history of part of the region, in which he suggests that Precambrian basement has been involved in the deformation of the region. His ideas have been disputed by Wheeler (1970) and Reesor (1970), among others.

Samples were collected from the gneissic wedge in northern Kootenay Arc (Revelstoke gneiss) and the granitoid gneiss in the western Cariboo Mountains (Quesnel Lake gneiss). Some samples from the Malton gneiss were collected by C. A.



- QLQuesnel Lake GneissMGFCFrenchman's CapRGTOThor-OdinV
- MG Malton Gneiss
 - RG Revelstoke Gneiss
 - V Valhalla

Giovanella of the Geological Survey of Canada. It was anticipated that the samples would exhibit a restricted range in Rb/Sr ratios, and hence would require precise measurement of their Sr⁸⁷/Sr⁸⁵ ratios in order to be dated.

I-3 Basic theory of rubidium-strontium geochronology

In common with other methods, rubidium-strontium geochronology is based on the well-known equation

$$N = N_{i}e^{-\lambda t} , \qquad (1)$$

where N is the number of atoms present at time t, N_i is the number of atoms initially present at t=0, and λ , the decay constant, represents the probability of decay of an atom in unit time. The equation is re-arranged to give

$$N_i = Ne^{\lambda t}$$
, (2)

where the quantity t is the time period from formation of the rock to the present, i.e. is the age, and N is the number of atoms in the rock at present.

Let the symbols D and P represent the number of daughter and parent atoms now observed in the sample, and let D_i and P_i represent the number of atoms at the time the sample was formed. If the system remained closed from that time until the present (no daughter or parent atoms are removed or added), then

$$D + P = P_i + D_j \qquad (3)$$

From equation 2,

$$\frac{D-D_i}{P} = e^{\lambda t} - 1 \tag{4}$$

and

$$t = \frac{1}{\lambda} \ln \left[1 + \frac{D - D_i}{P}\right]$$

For rubidium and strontium.

$$t = \frac{1}{\lambda} \ln \left[1 + \frac{Sr^{87}}{Rb^{87}} \right]$$

where Sr^{87*} is the radiogenic strontium accumulated in time t (i.e. $Sr^{87}-Sr_i^{87}$). This equation was used for several years before the difficulty of evaluating Sr_i^{87} was fully appreciated.

Equation (4) can be rearranged, and each side divided by a suitable index isotope (one that is neither radioactive nor radiogenic). For rubidium-strontium geochronology, Sr⁸⁶ is the most useful index isotope because it occurs in about the same abundance as Sr⁸⁷. Equation (4) then becomes

$$\frac{\mathrm{Sr}^{87}}{\mathrm{Sr}^{86}} = \left(\frac{\mathrm{Sr}^{87}}{\mathrm{Sr}^{86}}\right)_{i} + \frac{\mathrm{Rb}^{87}}{\mathrm{Sr}^{86}} \cdot (\mathrm{e}^{\lambda t} - 1) \quad . \tag{5}$$

The quantities $Sr^{\$7}/Sr^{\$6}$ and $Rb^{\$7}/Sr^{\$6}$ are measurable in the laboratory, and λ is known¹, leaving only t and $(Sr^{\$7}/Sr^{\$6})_i$ to be determined. The evaluation of the two quantities requires, of course, data from at least two cogenetic samples.

¹Uncertainties in λ are discussed in Appendix A-1.

In practice, several samples from each rock unit are analyzed, and the results are presented graphically. The first method of graphical presentation, proposed by Compston and Jeffery (1959), made use of the identity

$$\frac{Sr^{87}}{Sr^{86}} = \left(\frac{Sr^{87}}{Sr^{86}}\right)_{1} + \frac{Rb^{87}}{Sr^{86}} \cdot \frac{Sr^{87}}{Rb^{87}}$$

Rearranging terms leads to

$$\frac{\mathrm{Sr}^{87}}{\mathrm{Rb}^{87}} = \frac{\mathrm{Sr}^{86}}{\mathrm{Rb}^{87}} \left(\frac{\mathrm{Sr}^{87}}{\mathrm{Sr}^{86}} - \frac{\mathrm{Sr}^{87}}{\mathrm{Sr}^{86}}_{i} \right)$$

which is the equation of a straight line between Sr^{87}/Rb^{87} and $(Sr^{87}/Sr^{86})_i$. A sample thus defines a straight line on the graph, with the intercept on the Sr^{87}/Rb^{87} axis being the known Sr^{87}/Rb^{87} ratio of the sample, and the intercept on the $(Sr^{87}/Sr^{86})_i$ axis being the measured Sr^{87}/Sr^{86} ratio (Figure I-2). The slope of the line is the negative of the Sr^{86}/Rb^{87} ratio (i.e. it is always negative).



Samples from a cogenetic suite will define a number of lines on such a graph, one line for each sample. If the closed system assumption has been satisfied, the lines will intersect at a common point, the coordinates of which give the Sr^{87*}/Rb^{87} and $(Sr^{87}/Sr^{86})_i$ ratios for the suite (Figure I-2). The age of the rocks can be calculated from the equation

$$\frac{Sr^{87}}{Rb^{87}} = e^{\lambda t} - 1$$

An alternative graphical presentation of rubidiumstrontium data was proposed by workers at the Bernard Price Institute (Hales, 1960), and this BPI plot is the method in general use today. They pointed out that equation (5)

$$\frac{\mathrm{Sr}^{87}}{\mathrm{Sr}^{86}} = \left(\frac{\mathrm{Sr}^{87}}{\mathrm{Sr}^{86}}\right)_{i} + \frac{\mathrm{Rb}^{87}}{\mathrm{Sr}^{86}} \cdot (\mathrm{e}^{\lambda t} - 1)$$

is also an equation of a straight line, in this case between Sr^{87}/Sr^{86} and Rb^{87}/Sr^{86} , where each sample defines a point on the graph. If all samples are cogenetic, and if the closed system assumption has been satisfied, the points will define a straight line of slope $e^{\lambda t}$ -1 and intercept $(Sr^{87}/Sr^{86})_i$. (Figure I-3)

This latter plot is probably preferred because the fit of points to a line is easier to judge than the common intersection of a family of lines, and because recognized procedures exist for estimating uncertainties. Since it is in wider use, interpretation of rubidium-strontium data will be made in terms of that representation.



I-4 Interpretations

The simplest model to interpret is one in which a suite of samples has recorded only one event, such as its intrusion or a severe metamorphism. As a result of the event, all total rocks and minerals in the suite had the same strontium isotopic composition, but varied in their Rb/Sr ratios. At this initial time, all samples defined a horizon-tal line on the BPI diagram. As Rb⁸⁷ decayed to Sr⁸⁷, all points moved along lines with slope of -1, but maintained their colinearity, as shown in Figure I-4. After a time t_1 , the points, both total rocks and minerals, lie on an isochron of slope $e^{\lambda t_1}-1$.



Rb⁸⁷/Sr⁸⁶

A more complicated model is required if a second, less intensive, event has affected the samples. One possible effect of the event is that, although the total rock system remained closed, the minerals exchanged strontium and possibly rubidium. If exchange was complete, the minerals lost all memory of their previous history and once again lay on a horizontal line (dotted line in Figure I-5). When the samples are analyzed, the whole rocks and the minerals define two isochrons, with slopes of $e^{\lambda t_1}$ -1 and $e^{\lambda t_2}$ -1 respectively. The ages of the two events can thus be determined.



Rb⁸⁷/Sr⁸⁶

It is quite possible that the total rock systems will gain or lose rubidium and strontium as well, in which case it will be difficult or impossible to date the primary event. If strontium in the minerals is not properly homogenized, the mineral data will not provide a useful determination of the secondary event.

More complicated models, such as continuous diffusion or multiple event models are possible, but there is seldom enough information to apply them usefully.

The remainder of the thesis consists of a description of the digital data system in Chapter II, the analytical techniques in Chapter III, and the geological problem in Chapter IV. The conclusions reached in this study are summarized in Chapter V.

CHAPTER II

INSTRUMENTATION

II-1 Introduction

In the past few years, many mass spectrometer laboratories have moved toward some form of digital processing of their data. In a simpler configuration, it has taken the form of off-line processing - digitization of the mass spectra in the course of the analysis, followed later by computer processing (Weichert et al., 1967; Cumming et al., 1971; Stacey et al., 1971, 1972). More complex systems involve on-line processing of spectra, in which data are transmitted directly to a computer, so that reduction of the spectra is carried out during the analysis (Wasserburg et al., 1969; Russell et al., 1971). The primary advantages of a digital system are convenience, and improvement of precision and reproducibility. In addition, an on-line system provides a means of monitoring the quality of an analysis during the run, so that all analyses can be made to a specified degree of precision.

The first digital data system at the University of British Columbia was an off-line system designed by Weichert (1965) for the laboratory's gas source mass spectrometer (Weichert et al., 1967). The measuring system at that time was an ion current amplifier of the servo-voltmeter type, its output being the shaft rotation of a motor-driven potentiometer (Stacey et al., 1965). Analog-digital conversion was conveniently provided by a shaft position encoder. Twice per second, the four decimal digits from the encoder were read into a buffer and subsequently punched serially onto paper tape. A fifth character indicated the magnet scan direction (up-mass, down-mass or no scan) and the measuring system attenuation, or shunt. In this way, a complete representation of the trimethylead-ion spectrum was stored on the tape. A study of signal and noise spectra showed that the paper tape contained all the useful information in the mass spectrum (Weichert et al., 1967).

A mass spectrometer run consisted of several scans of the spectrum, each scan beginning at the high-mass end. First, baseline readings (zero signal level) were recorded, then the magnetic field was varied to scan down the spectrum. More baselines were taken at the low-mass end of the spectrum, before the peaks were scanned again, this time in the reverse order. Baselines were recorded once more, and the scan terminated.

Processing of the tape was carried out using the facilities of the Computing Centre. Each scan was treated as a complete unit. Data were first filtered digitally, then searched for maxima and minima. Baselines were calculated from the appropriate data, and subtracted from the maxima and minima to produce the peak heights. The peaks were identified and stored, together with their time of occurrence. Pressure scattering calculations were determined, and output, together with the peak heights and times. Finally,

the lead isotope ratios were calculated.

The system, with minor modifications, was in use until late 1969, when the electronic supplies for the gas source mass spectrometer were re-built.

By late 1968, the laboratory had two solid-source mass spectrometers in operation, as well as the gas source instrument, though only the latter was provided with digital output. Instead of extending Weichert's system to the solid source machines, it was decided to set up a more sophisticated system, capable of providing simultaneous data reduction for all three mass spectrometers. Since the system incorporated a digital computer, it was expected that full on-line processing of spectra could be achieved, at least for the solid source machines, and that the computer could supervise the operation of the mass spectrometers.

The present writer was responsible for the overall design and implementation of the system as it now exists. With his help, D. L. Mitchell (1971) designed and built the computer-mass spectrometer interface, and R. D. Meldrum designed and built the tape-drive interface and a selector channel. This writer was entirely responsible for the computer programming, all of which was done in assembly language.

II-2 Hardware

The equipment to be discussed in this section includes the hardware at the mass spectrometer, the computer, and the interface between the two devices.

The hardware at each mass spectrometer consists of the measuring system, a digital voltmeter, a digital display and an output request switch. The measuring system is currently a hybrid D.C. amplifier, consisting of an electrometer vacuum-tube preamplifier and a conventional D.C. amplifier. The voltmeter digitizes the output of the measuring system, and is discussed more fully in the following paragraph. The digital display is used in conjunction with the 8-position output request switch to display data from the computer.

The digital voltmeter is a Data Technology DT-344-2 4-digit meter, 1.000 volts full scale, of the dual-slope integrating type. The input signal discharges a capacitor for a period of 50 msec (10,000 counts of a 200 khz internal oscillator). At the conclusion of the interval, the input signal is disconnected, and a precise current source is used to re-charge the capacitor. The time taken for the recharging operation is measured by counting the cycles of the internal oscillator. The number of counts is proportional to the input voltage, and it is this number which is displayed at the conclusion of the measurement. Binary coded decimal (BCD) outputs are also provided, together with a signal to indicate the operation is complete (the PRINT signal). The measurement cycle is repeated 5 times each second.

The computer used in the study is an Interdata Model 4, manufactured by Interdata Inc. of Oceanport, New Jersey. Its major components are the processor, the memory, and the peripheral devices (Figure II-1). The central pro-





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cessor, under control of a program resident in a read-only memory, decodes and executes user instructions, performs logical and arithmetic operations, supervises communication with external devices, and performs a variety of tasks associated with the running of programs. The memory, which currently consists of 8,192 16-bit words, provides storage for user programs and data. The peripheral devices include an ASR-33 Teletype, three mass spectrometers, and an analog-digital converter, all of which are connected to the multiplexor bus. A selector channel, designed and built in the laboratory, provides data access independent of the central processor for a magnetic tape drive. As this thesis was being written, a link to the Computing Centre's IBM Duplex 360/67 was completed.

The processor recognizes an extensive instruction set (about 65 user instructions). It has sixteen 16-bit registers, all of which can be used as accumulators. An internal program status word (PSW) supervises sequencing of instructions, masks interrupts of various types, and contains status information. The general architecture of the computer matches that of the IBM 360 series.

Communication between the computer and external devices attached to the multiplexor bus is either programcontrolled or interrupt-controlled. The former requires that the computer wait for the particular device to become ready before initiating a data transfer, so that the computer is fully dedicated to the input/output operation. Interruptcontrolled input/output, however, allows the computer to

proceed with other tasks. When a device is ready for a data transfer, it interrupts the computer, which immediately services the device and then returns to its previous task when the input/output operation is complete. The interruptcontrolled form of communication was used in this study, as it permits a greater flexibility in programming.

The mass spectrometer-computer interface (Mitchell, 1971) controls the flow of information between the two devices. The interface consists of the standard logic required for multiplexor bus operations, and special logic required for the mass spectrometers. The parameters read by the computer include the digital output of the measuring system, and the setting of the output request switch. Output to the mass spectrometers includes BCD data to the 5-decade digital display, and frequency control of an oscillator that determines the speed of the magnetic scan drive.

All these functions are summarized in Table II-1.

TABLE II-1

INPUT MODE

READ

- 1) 5 BCD digits from measuring system
- 2) shunt number
- 3) scan direction
- 4) output request switch

STATUS

reserved for future use

OUTPUT MODE

WRITE

- 1) 5 BCD digits to digital display
- 2) decimal points on display
- 3) magnet scan speed

OUTPUT COMMAND

- decade selection for read/write
- 2) scan speed modifications

II-3 Filtering

The digital output of the measuring system lends itself to the use of digital filters for improving the signalto-noise ratio of the data. The information content of the signal occurs at low frequencies, hence it is advantageous to employ a low pass filter (Weichert et al., 1967; Russell et al., 1971).

The filter used in this study is shown in Figure II-2, represented in both the time and frequency domains. It is apparent that frequencies above about 0.6 hz. are almost completely rejected. The filter is applied by first averaging all possible consecutive sets of seven points. Alternate points are discarded, and those remaining are averaged with a three-point filter. The third stage is filtering with a five-point filter, after which alternate points are again discarded. For each summation, the end-points are halved. The repetitive averaging is entirely equivalent to multiplying each of the 19 points included in the filter window by its appropriate weight (Figure II-2a), but is computationally faster, since multiplications are avoided.

An aliased power spectrum of the measuring system baseline noise is shown in Figure II-3, both before and after filtering. Since the digitization rate is 5 per second (5 hz.), noise at frequencies above the Nyquist frequency (f_N) of 2.5 hz. is folded back to lower frequencies. Noise at frequencies (5 n ± 0.6) hz. (n = 1,2,...) will contaminate the signal in the region passed by the filter, but such contributions are





Frequency (hz)

believed to be negligible. The large peak at low frequencies in the power spectrum is probably a result of baseline drift during the time the raw data were taken.

II-4 Spectrum scanning

Two alternatives were considered for scanning of the spectrum. One of these was peak switching, in which the magnet current is altered in discrete steps, large enough to move directly from one peak to the next. The primary advantage of this method is speed of analysis, since virtually all measurement time is spent monitoring the peaks, while its primary disadvantage is the problem of recovery of position on the peak tops. If the peak tops are not completely flat, this problem introduces an additional uncertainty into the data. Wasserburg et al. (1969) have, however, used this approach with remarkable success.

The other alternative is magnetic field scanning, similar to that employed by Weichert (1965). The problem of recovering peak position and the requirement of flat peak tops are removed, but considerable time is spent collecting information between the peaks, especially if the mass spectrometer has relatively high resolution. With magnet scanning, therefore, a longer time is required to obtain the same amount of data, which means that demands on the long-term stability of the ion beam are greater.

The method used in this study is magnetic field scanning, but the computer is used to alter the scanning rate.

In the region between peaks, the scanning rate is greatly increased, but when a peak is detected by the computer, the scan rate is slowed, so that an accurate determination of the peak amplitude can be made. The computer detects peaks by comparing two consecutive digital voltmeter readings, and alters the rate if they differ by more than 0.5% of full scale. The sign of the difference between the points determines whether the rate is increased or decreased.

II-5 The digital data system

The system as it presently exists is capable of operating in three modes - filtering, data acquisition, and on-line reduction. The first two were not used in this study, so they will be discussed only briefly.

Filtering mode:

This is the simplest mode of operation, and the only one that can currently be used by all three mass spectrometers simultaneously. The PRINT signal from a digital voltmeter is used to interrupt the computer, whereupon the meter is read, and its reading filtered as described in the previous section. When a filtered point becomes available (after every four interrupts), it is written onto the digital display at the mass spectrometer. The operator records the appropriate readings from the display. This mode is, in practice, seldom used, except for rather unstable signals, where it is advantageous to make peak measurements as quickly as possible.

Data acquisition mode:

This mode is used only with the gas source mass spectrometer, and is a modification of the procedures described by Weichert (1965). Data are filtered as in the filtering mode, but additional information such as magnet scan direction and measuring system attenuation is also required. It is combined with the filtered data and stored in a buffer, which, when full, is output onto magnetic tape. This tape is processed later at the Computing Centre by updated versions of the program described by Weichert et al. (1967).

On-line reduction:

This mode provides for on-line reduction of solid source spectra of both lead and strontium. Since it was used in this study for measurement of strontium isotope ratios, it will be discussed in terms of this element. Only one mass spectrometer could be provided with on-line reduction at any one time, because of computer memory limitations. (The memory size has recently been doubled, and this limitation no longer applies.)

The program begins by setting constants and clearing arrays, and prompting the user to enter a sample identification and to select program options through the teletype. The computer then waits for an interrupt from the mass spectrometer.

The operator begins the analysis at the up-mass end of the spectrum by permitting the PRINT commands from the digital voltmeter to interrupt the computer. At each inter-

rupt, the mass spectrometer is read and the data are filtered, as described previously.

The first data that are taken are baseline points, which the computer recognizes by the absence of a magnet scan indication. The filtered baseline points for each shunt are summed and stored in an array from which the average baseline values are later calculated.

When the operator begins to scan, the computer recognizes the fact and treats the points somewhat differently. The raw points are compared to determine if the scan rate needs to be altered. Filtered points are searched for relative maxima by summing them in consecutive groups of three, and examining the sums under a five-point window. If one is found, the three points comprising the sum are examined, and the largest of them is taken as the maximum. It, together with its time, is stored in a table of maxima. (Times are derived from a filtered point counter.)

Baselines are taken again at the low-mass end of the spectrum, and the spectrum is scanned in the up-mass direction. Baselines are again measured, and the end-of-scan button is pressed to initiate scan processing. This begins with the subtraction of baselines, corrected for drift, from all the maxima in the table. The peaks are automatically identified, a linear correction for growth or decay is applied to them, and the isotopic ratios are calculated. The Sr⁸⁷/Sr⁸⁶ ratio is corrected for fractionation. Peak heights, their times, and the isotopic ratios are printed on the tele-

type and serve as a permanent record of the analysis. The isotopic ratios can also be output on the display at the mass spectrometer at the request of the operator. At the option of the operator, the filtered data may be stored on magnetic tape. Each scan requires about three minutes.

II-6 Conclusions

The system described in the previous sections has been used extensively in the laboratory for analyses of lead (by gas and solid source), rubidium, and strontium. Over 1000 analyses have been made with it in the last two years. The precision obtained with the system depends on the element being analyzed. For strontium, a precision of 0.02% for the Sr^{87}/Sr^{86} ratio is routinely achieved (Chapter III-5), a value which is quite adequate for the purposes of this study.

Perhaps the principal advantage of the system is its great flexibility. With minor modifications to the hardware, it should be possible for the computer to control all aspects of the analysis. The recent completion of an on-line connection to the IBM Duplex 360/67 at the Computing Centre enables the system to employ the much larger computing resources of the IBM computer.
CHAPTER III

ANALYTICAL TECHNIQUES

III-1 Introduction

The analytical techniques employed in this study are mostly conventional ones, the most notable exception being the determination of rubidium and strontium concentrations by an x-ray fluorescence method. Since the procedures are an important part of obtaining results of high precision, they are described in this chapter.

III-2 Measurement of rubidium and strontium concentrations

The samples were prepared as follows:

Rocks were first examined for weathered or discoloured surfaces, which were chipped off. About 2-5 kgm of the rock were passed through a jaw crusher, and then through a cone crusher. At this point, the sample was split, and a portion of about 200 gm was taken for whole rock analysis. This portion was crushed to pass 100 mesh by running it through a pulverizer two or three times. Any particles that did not pass 100 mesh (mostly platy minerals) were crushed in a Spex mill until they were sufficiently fine.

Approximate Rb/Sr ratios were determined by x-ray fluorescence for all samples in order to select those best suited for dating. The machine used was a Philips unit, operated by the Department of Geological Sciences. It consists of a PW1011/60 high voltage generator, a PW1050/85 x-ray generator, a PW4025 scintillation counter, a PW4231 scaler, a PW4261 timer, a PW1365 pulse shaper, a PW4280 amplifier/ analyser, and a PW1362 ratemeter. A few grams of rock powder were introduced into the x-ray fluorescence unit, and the portion of the x-ray spectrum including the rubidium and strontium peaks was scanned. An estimate of the Rb/Sr ratio of a sample was obtained from the spectrum by comparing it to that of a standard. The uncertainty of the estimate was about 5 percent. Rubidium and strontium concentrations were also individually estimated, but substantial errors often occurred unless the standard and unknown were chemically quite similar. The operating parameters of the x-ray fluorescence unit are given in Table III-1.

TABLE III-1

Operating parameters for the x-ray fluorescence unit. (Ryan, in preparation)

Target material:	molybdenum
Tube voltage:	50 kV
Tube amperage:	30 mA
Pulse height analyser:	
attenuation:	5
window:	2.70 (lower level)
	4.00 (width)
time constant:	0.5 seconds
Crystal:	lithium fluoride (200)
Collimator setting:	fine

Once the approximate Rb/Sr ratios were known, samples with a suitable spread in that ratio were selected for dating. Their Rb⁸⁷/Sr⁸⁶ ratios were determined more precisely by an x-ray fluorescence technique developed by Ryan (in preparation), and their Sr⁸⁷/Sr⁸⁶ ratios were measured mass spectrometrically with the aid of the on-line system described in Chapter II.

Rubidium and strontium concentrations have conventionally been determined by isotope dilution. The technique entails adding a known amount of rubidium or strontium of radically different isotopic composition (spike) to a weighed quantity of rock powder. The powder is processed chemically to separate the rubidium or strontium, and the isotopic composition of the mixture of spike and sample is measured on the mass spectrometer. Since the isotopic composition of both spike and sample is known, as is the amount of spike added and the weight of rock used, the concentration of rubidium or strontium in the sample can easily be calculated.

Recently, the isotope dilution technique has been replaced to some extent by x-ray fluorescence methods (Doering, 1968; Compston et al., 1969; Fairbairn and Hurley, 1971). The primary advantages are speed and simplicity; ten to fifteen samples can easily be analyzed in a few hours, and no sample dissolution is required.

About three or four grams of rock powder are formed into a pellet, which is surrounded by a 50-50 mixture of boric acid and bakelite powder, and the sample is compressed

hydraulically. The resulting pellet is about 3 cm in diameter, and about 0.8 cm thick.

The measurement is made by comparing the unknown samples with a group of four United States Geological Survey standards. For each pellet, readings are taken at specific points in the x-ray spectrum, the points being the incoherently (Compton) scattered molybdenum K_{α} peak, the rubidium and strontium peaks and a baseline position. In addition, the molybdenum K_{α} peak itself is measured on a bakelite disc for 20 seconds in order to monitor the stability of the x-ray At all other positions, counts are taken for 100 beam. seconds. A typical analysis involves measuring the four standards, usually in duplicate, and the unknowns. Most samples reported in the thesis were analyzed in duplicate, and on different days, but measurements were made on the same pellets.

The calculation of the rubidium and strontium concentrations, and the Rb/Sr ratios, were done by computer. The standards, for which rubidium and strontium concentrations and the mass absorption coefficient (μ) were known, were first used to define a line relating μ to the reciprocal of the Compton scattered peak height. The μ -values for the unknown samples were determined from the line. Lines were computed for the standards by comparing the rubidium or strontium concentrations and the adjusted peak height (peak height multiplied by μ). The rubidium and strontium concentrations were obtained from the latter plots, and were used to calculate

the Rb/Sr ratios. The precision of the results will be discussed in a later section, but was not worse than 3% for the Rb/Sr ratios.

The standards used for the x-ray fluorescence determination of Rb/Sr ratios were standard rocks distributed by the United States Geological Survey. The samples are a basalt, BCR-1, an andesite, AGV-1, a granite, G-2, and a granodiorite, GSP-1. Values for their rubidium and strontium concentrations were obtained from Fairbairn and Hurley (1971) and De Laeter and Abercrombie (1970), and are given in Table III-2, together with the values used in this study, which are denoted by an asterisk. The apparent differences between the samples are not significant.

TABLE III-2

Sample	Rubidium (ppm)	Strontium (ppm)	<u>Rb/Sr</u>	Reference
BCR-1	48.2 *	331 *	.146	1
	48.0	332	.145	2
AGV-1	67.7 67.0 *	663 * 657	.102	1 2
GSP-1	253	235 *	1.08	1
	255 *	235 *	1.09	2
G-2	171	480 *	.356	1
	169 *	475	.356	2

5

Rubidium and strontium concentrations of standard rocks.

* Values used in this study

References: 1 - Fairbairn and Hurley (1971) 2 - De Laeter and Abercrombie (1970)

μ values for the rock standards were obtained The by direct measurement and by calculation. The direct measurement, carried out by B. D. Ryan, employed the x-ray technique previously described, except that chemical standards of known μ 's were used to define the line relating μ and the reciprocal of the Compton-scattered peak height. The μ values for the rock standards were obtained from this line, since their Compton-scattered peak heights were known. The calculation of the μ -values, carried out by the writer, made use of chemical analyses of the rocks, and tables of the μ values of their constituent elements. The weight percent of each element was multiplied by its μ value and the products summed to yield the μ value. The results obtained are summarized below.

	TABLE III-3	-
µ values	for the U.S.G.S.	standard rocks
Standard	Direct	Calculated

	me as ar emerite	
GSP-1	6.76	6.67
AGV-1	7.41	7.33
BCR-1	9.65	9.50
G-2	6.07	6.04

The directly measured results were used for this study, because they are believed to be better determined. The calculated μ 's are quite sensitive to uncertainties in the measurement of elements with high μ values, such as However, both sets of μ values gave essentially iron.

similar Rb/Sr ratios for the unknowns.

III-3 Chemical preparation of samples

The chemical procedure for the preparation of samples for isotopic analysis was modified from United States Geological Survey procedures by Ryan (in preparation). About 0.5 gm of rock powder were dissolved in 10 ml of 48% hydrofluoric acid and about 1 ml of 9M sulphuric acid. Dissolutions were carried out in 50 ml Teflon beakers, and usually required 24 to 48 hours. After the sample was in solution, the beaker was heated strongly to drive off excess sulphuric acid. The residue in the beaker was dissolved in about 10 ml of 6N hydrochloric acid, and centrifuged. The solution was transferred to an ion exchange column, consisting of about 20 gm of Dowex 50 X-8 ion exchange resin. The sample was eluted through the column with 6N hydrochloric acid. Collection of the eluant began after 25 ml of solution had passed through the columns. About 40 ml of solution, which contained both rubidium and strontium, were collected.

A second, similar column was used to separate the rubidium and strontium. The 40 ml of solution collected from the first column were taken to dryness and re-dissolved in a minimum volume of 2N hydrochloric acid. The sample was transferred to the column, and eluted with 2N hydrochloric acid. After 85-90 ml of acid had passed through the column, about 40 ml of solution were collected. This represented the strontium fraction. The sample was reduced in volume,

transferred to a 5 ml beaker, and taken to dryness.

III-4 Mass spectrometry

The mass spectrometer used was a 30 cm, 90°, singlefocusing instrument. Samples were analyzed using the triple filament technique, with filaments of .75 mm x .025 mm rhenium The strontium chloride was dissolved in a small amount ribbon. of hydrochloric acid and transferred to the outgassed filaments with a disposable glass pipette. A drop was placed on each of the side filaments and a current of about 0.8 A was passed through them. Another drop was added after the sample had dried, and the procedure repeated until all the sample was on the filaments. The current through them was increased to about 1.2-1.4 A for a minute, after which time it was increased until the filaments glowed a dull red, (about 1.7 to 2.1 A) and was held there for about a minute. The filaments were placed in a filament block, a centre filament was added, and the block introduced into the mass spectrometer. The mass spectrometer was left to pump until the pressure, measured at the ion source, fell below 5 x 10^{-7} torr.

The mass spectrometer supplies were switched on about 15-20 minutes before the analysis began. The accelerating voltage was set at 5 kV, and the magnet current to about 250 mA. The centre filament supply was set to about 2 A (approx. 1300° C) then turned slowly up to 3 A (approx. 1500° C) over a period of about 15 minutes. The slow increase in current was necessary because at temperatures above about

1000° C, the samples outgassed significantly and the pressure rose. More rapid heating gave rise to a very high pressure in the source region (>1×10⁻⁵ torr.).

Above a filament current of about 3 A, the region of the strontium spectrum was searched for the rubidium peaks. The filament current was increased in steps of 0.1 A until the rubidium was detected. (Rubidium is easily ionized - 1 µgm of rubidium will produce an intense signal.) At this point, the behaviour of the rubidium peaks was observed in order to obtain an idea of the amount of rubidium contamination present. A slowly growing or decaying peak indicated relatively little rubidium, while continuous rapid growth for at least ten minutes suggested considerable rubidium. Samples with low contamination were usually heated strongly for about 5 minutes, or until the rubidium signal was < 10^{-15} A, by raising the centre filament temperature to about 2500° Samples with significant rubidium contamination were left С. to heat for an hour or so at 1500° C, then heated strontly until the rubidium peak was suitably small. After the strong heating step, the filament current was reduced to 2.5 to 3 A for a few minutes in order to allow the source region to cool and the machine pressure to drop.

The next step in the analysis was to increase the centre filament current until a strontium spectrum was detected. Focus conditions for the source were optimized, and the current was slowly increased. The current was raised until the Sr^{88} ion current was about 2×10^{-11} A, or until the centre filament

temperature was about 1850° C. If the signal strength was insufficient, the side filament current supply was turned on, and the current was increased until the Sr⁸⁸ signal was sufficiently large. The signal was allowed to stabilize for a few minutes, during which time a check was made for the Rb⁸⁵ peak. If one was found, and the Sr⁸⁸ signal was increasing, the sample was again heated strongly with the centre filament as described previously. If a Rb⁸⁵ peak was found, and the strontium signal was decaying, no attempt to remove the rubidium was made, and the analysis was continued. For most runs it was possible to remove the Rb⁸⁵ peak completely (Rb⁸⁵ < 10^{-15} A). The Sr⁸⁸ ion beam was then monitored, and if it appeared stable on the chart recorder, the analysis was begun.

The analysis itself consisted of at least five complete scans of the strontium spectrum. If a rubidium peak was present, but was too small to be detected by the computer ($<2.5\times10^{-14}$ A), its peak height was recorded on the chart so that a correction could later be applied. The peaks usually scanned were the Sr⁸⁸, Sr⁸⁷ and Sr⁸⁶ peaks and, if necessary, Rb⁸⁵. Sr⁸⁴ was measured only if a Sr⁸⁴ spike was used. During the analysis the normalized Sr⁸⁷/Sr⁸⁶ ratio was recorded, and a running estimate kept of its standard deviation of the mean ($\overline{\sigma}$). The run was usually terminated when $2\overline{\sigma}$ for the ratio fell below 0.03%, but not before five scans had been taken.

For some analyses, a stable beam was difficult to obtain, probably due to a poor sample loading. It was found

that if the sample was heated strongly by the centre filament for a few minutes, the strontium signal was usually more stable afterwards. An alternative procedure was to increase the side filament current briefly to produce the same effect.

III-5 Precision

As was stated in the previous section, all strontium analyses were continued until $2\overline{\sigma}$ for the run fell below 0.03%. If the errors are random and normally distributed, repeated analyses of a standard should also fall below this value. Replicate analyses of an inter-laboratory standard, the Eimer and Amend strontium carbonate, are shown in Table III-4 and have a 95% confidence limit of $.01_6$ %, which compares favorably with the average value for the individual analyses of about 0.02%. The agreement of estimates suggests the errors are indeed random.

A more stringent test of precision is duplicate analyses of rock samples, which includes separate chemical preparation of the samples. Six rocks were analyzed in duplicate, and the results are shown in Table III-5. An estimate of precision from these results is 0.02_7 % (95% confidence level), in reasonable agreement with the previous values. On the basis of the three different estimates of precision, a value of 0.02% for all analyses reported in this thesis is indicated.

This value may be compared to that obtained at the California Institute of Technology by Wasserburg and co-workers.

Papanastassiou and Wasserburg (1969) have discussed the precision of their system, which is generally regarded as representing the state of the art. Their value appears to average about 0.01%, as estimated from individual analyses and from replicate analyses of a sea-water standard. The precision obtained in this study is thus within a factor of two of that obtained at C.I.T.

It should be noted that only about 10 scans were taken for each analysis reported in this thesis, whereas Wasserburg and associates usually require about 100. For geochronological studies of British Columbia, such as are described in this thesis, the larger number of scans was considered unacceptable, whereas the 0.02% precision appears satisfactory.

Ryan (in preparation) has estimated the precision of Rb/Sr ratios determined by x-ray fluorescence to be 3% at the 95% confidence level. Duplicate analyses of some samples are tabulated in Table III-6, and confirm Ryan's estimate. For the samples studied in this research, the isotopic analyses and x-ray fluorescence analyses make comparable contributions to the age uncertainties.

TABLE III-4 Replicate measurements of Eimer and Amend strontium carbonate.

	Date		<u>Sr⁸⁷/Sr⁸⁶</u>
1971	May 13 May 15 May 16 June 5 June 7 July 3		0.7083 0.7079 0.7080 0.7083 0.7082 0.7082
1972	May 19 May 22		0.7083 0.7082
		average:	0.7082
		2 σ	0.0001,

TABLE III-5

Duplicate Sr⁸⁷/Sr⁸⁶ measurements for rock samples.

Sample	<u>Sr⁸⁷/Sr⁸⁶</u>
401-10	0.7196 0.7197
401-11	0. 7304 0. 7304
R2-1	0.7101 0.7099
R1-T-1	0.7148 0.7149
18AF71	0.7127 0.7128
R6 - 2	$0.7176 \\ 0.7178$

TABLE III-6

Replicates of rubidium & strontium concentration measurements.

Sample	<u>Rb (ppm)</u>	Sr (ppm)	<u>Rb/Sr</u>
2BF71	143	460	0.311
	143	459	0.312
	141	457	0.309
	142	460	0.309
R1-4	76.1	266	0.286
	75.7	266	0.285
	75.6	272	0.278
	76.5	271	0.282
R1-T-1	101	201	0.502
	101	199	0.508
3F71	127	327	0.388
	126	327	0.385
R5-2	86.5	210	0.412
	87.4	210	0.416
	87.2	211	0.413
5F71	109	521	0.209
	110	522	0.211
R2-1	79.7	427	0.189
	79.9	432	0.185
R3-1	85.0	228	0.373
	85.6	229	0.374
R3-T	73.7	230	0.320
	74.8	234	0.320

CHAPTER IV THE GEOLOGICAL PROBLEM

IV-1 Background

The general geological elements of southeastern British Columbia are shown on Figure IV-1, together with the locations of areas studied. The major elements are the Purcell Anticlinorium, the Kootenay Arc, and the Shuswap Metamorphic Complex. The latter two are included in the Omineca Crystalline Belt, which extends northwestward into the Yukon. To the south it disappears beneath younger rocks.

The Purcell Anticlinorium is composed primarily of sediments of the Belt-Purcell Supergroup. Where the base of the sequence is exposed, it is seen to rest on crystalline basement, which is 1600-1800 m.yr. old (Obradovich and Peterman, 1968). The Belt-Purcell sediments are unconformably overlain by the late Precambrian Windermere sequence in some places, and by Cambrian rocks in others. The comprehensive rubidium-strontium study by Obradovich and Peterman (1968) indicated an age of about 850 m.yr. for the youngest sediments, with other periods of sedimentation at 1050 m.yr. and 1250 m.yr. The East Kootenay Orogeny (White, 1959) terminated the Purcell sedimentation.

The Kootenay Arc includes rocks of late Precambrian to Triassic age. It is a belt of highly deformed rocks which have been variably metamorphosed. Its structure and stratigraphy have recently been described by Fyles (1964, 1967, 1970a),



QLQuesnel Lake GneissMGMalton GneissFCFrenchman's CapRGRevelstoke GneissTOThor-OdinVValhalla

Read (1966), Crosby (1968), Ross and Kellerhals (1968), and Ross (1970). The Nelson and Kuskanax Batholiths are major intrusions within the arc; the former has been dated at about 165 m.yr. (Nguyen et al., 1968). A lead isotope study of galenas from the Arc (Sinclair, 1966; Reynolds and Sinclair, 1971) indicated that, in its southern part, it may be underlain by 1500-1700 m.yr. basement.

The Shuswap Complex is an extensive belt of highgrade, highly deformed metamorphic rocks. Its boundaries generally coincide with the sillimanite isograd. The time of metamorphism has long been in dispute, estimates ranging from Mesozoic (Cairnes, 1929; Wheeler, 1970) to Precambrian (Jones, 1959), though recent mapping favours a late Paleozoic or Mesozoic age (Ross and Kellerhals, 1968; Reesor and Moore, 1971). (A generalized geological time scale is shown in Table IV-1.)

It was stated in the first chapter that a major objective of this study was to date certain gneisses within the southern Omineca Crystalline Belt of British Columbia. Proposals have been made that these gneisses represent Precambrian crystalline basement. Their complex metamorphic and deformational history make them difficult to date from geologic evidence, so an attempt was made to date some of them radiometrically.

The presence of Precambrian crystalline basement is important for several reasons. One concerns a hypothesis proposed by Ross (1968, 1970) outlining a deformational

history of the area, a central part of which is the participation of Precambrian basement in the regional deformation. Another reason concerns plate tectonic reconstructions for the region, which require geochronological data. A third reason is related to the evidence that the area was once a continental margin (for part of its history), which, if true, could place severe constraints on the occurrence of Precambrian crystalline basement.

<u>TABLE IV-1</u> Simplified geological time-scale.

ERA	PERIOD	TIME (m.yr.)
CENOZOIC	Quaternary	0 - 10
	Tertiary	10 - 70
<u></u>	Cretaceous	70 - 135
MESOZOIC	Jurassic	135 - 190
	Triassic	190 - 225
	Permian	225 - 280
	Carboniferous	280 - 350
PALFOZOIC	Devonian	350 - 400
PALEOZOIC	Silurian	400 - 440
	Ordovician	440 - 500
· ·	Cambrian	500 -∿600

PRECAMBRIAN

>600

IV-2 Theories of origin of the gneiss domes

Ross's hypothesis for the deformational history of the region, among other things, accounts for the origins of three domal complexes that lie within the eastern edge of the Shuswap Complex at about 80 km intervals (Figure IV-1). From north to south they are Frenchman's Cap (Wheeler, 1965; Fyles, 1970; McMillan, 1970), Thor-Odin (Reesor, 1970; Reesor and Moore, 1971), and Valhalla (Reesor, 1965). An opposing view regarding their origins has been put forward by Reesor and Moore (1971). These views will now be discussed.

Ross (1968, 1970) and Ross and Kellerhals (1968) have proposed that the domes were produced as a result of interference between two different directions of folding. In their view, sediments that had been deposited on a gneissic basement were first deformed when a slice of basement was detached and was thrust into them. This first phase of deformation thus produced large recumbent folds, cored in their anticlinal parts by basement gneiss. The folds were later refolded about different axial planes, giving rise to the domal structures.

The first phase of deformation, which began at some time after the early Cambrian, saw the formation of large recumbent folds or nappes, most of which closed towards the east. At some later time, probably after the early Permian, but before the late Triassic, structures of the second phase developed as a result of reaction between the easterly movement of the nappes and the more rigid Purcell mass. The third

and final phase of deformation was backfolding of the nappes, again as a result of reaction against the Purcell Anticlinorium. The timing of this last phase is post Triassic, but before the intrusion of the Nelson Batholith.

Metamorphism accompanied all three phases of deformation, reaching a maximum during the second phase. Ross and Kellerhals (1968) suggest that the metamorphism affected most, if not all, of the Shuswap Complex, and that the major metamorphism of the Shuswap was post early Permian. They do not find structures related to the first two phases of deformation within the Triassic Slocan Group, and therefore conclude that the major Shuswap metamorphism had ended by the Triassic.

Reesor (1970) and Reesor and Moore (1971) have proposed a somewhat different origin for the domes. In their view, the first step was the appearance of a narrow, northnorthwesterly trending zone of high heat flow. Migmatization and metamorphism followed, occurring synchronously with interfolding and penetration of the mobile migmatites into metasedimentary gneisses. The folds permitted local upwelling of migmatite and granitic gneiss, thus concentrating hotter materials beneath easterly-trending antiforms. Diapiric uprise of migmatite and granitic gneiss took place beneath the antiforms and gave rise to the domal structure.

Reesor and Moore (1971) have also discussed the possible timing of the Shuswap metamorphism. They point out that, although it is rather difficult to correlate metamorphic rocks with their unmetamorphosed equivalents, some structural

successions can be found within the Shuswap Complex that appear to correspond to known sequences outside it. On this basis, rocks which range in age from late Precambrian to Mississippian are present in the Shuswap Complex, so the main metamorphism cannot be earlier than late Paleozoic. Furthermore, the Triassic Slocan Group may also extend into the Complex, indicating that the beginning of the Shuswap metamorphism is post Triassic.

The age of the gneisses thus becomes an important test of these hypotheses. According to Ross, the gneisses represent crystalline basement and are Precambrian in age, perhaps as old as 1600-1800 m.yr. Reesor and Moore, on the other hand, argue that the gneisses were formed, for the most part, from Windermere sediments at the time of the Shuswap metamorphism, which they place at about 150 to 250 m.yr. ago.

IV-3 The Revelstoke gneiss

In order to date the gneisses, samples were obtained from the gneissic wedge northeast of Revelstoke, an area mapped by Ross (1968). The major structure in the area is an easterly-verging recumbent anticline with a gneissic core. It has undergone at least three episodes of deformation. The hypothesis proposed for the evolution of the area has already been discussed.

On the basis of the relationship between the gneiss and amphibolitic bodies, Ross has suggested that the amphibolites were emplaced as basic dikes within the gneiss prior to

the first phase of deformation. The gneiss therefore must have had a metamorphic history prior to the time of the first phase, which follows the early Cambrian. Furthermore, Sinclair (1966) had postulated that a 1700 m.yr. basement existed beneath the southern part of the Kootenay Arc, and similar ages are found for rocks from boreholes 200 km to the east. Ross (1968) therefore suggested that the gneiss could be as old as 1700 m.yr., and that it formed a basement upon which metasediments now found in the Shuswap Complex were originally deposited.

TABLE IV-2

Rubidium & strontium measurements from the Revelstoke gneiss.

Sample	<u>Rb (ppm)</u>	Sr (ppm)	Rb ⁸⁷ /Sr ⁸⁶	Sr ⁸⁷ /Sr ⁸⁶
R1-T-1	101	200	1.46	0.7148
R1-T-2	64.2	277	0.671	0.7120
R1-1	55.5	342	0.470	0,7095
R1-2	113	225	1.45	0.7147
R1-4	76.0	269	0.818	0.7137
R1-5	86.7	205	1.23	0,7139
R2-1	79.8	430	0.537	0.7100
R3-T	74.2	232	0.926	0.7130
R3-1	85.3	229	1.08	0.7131
R4 - T	92.3	217	1.23	0.7139
R5-T	86.5	217	1.15	0.7168
R5-1 *	85.9	195	1.28	0.7175
R5-2	87.0	210	1.20	0.7170
R6-1	84.9	211	1.17	0.7173
R6-2 *	104	183	1.65	0.7177

*Not used for isochron calculation

The writer, with the assistance of B. D. Ryan, collected samples of the granitic gneiss from locations along

the Trans-Canada Highway and Laforme Creek (Figure IV-2). The results are given in Table IV-2 and plotted on Figure IV-3. Two isochrons have been obtained, one with an age of 740 \pm 30 m.yr., and the other of age 240 \pm 30 m.yr. (All uncertainties are 95% confidence limits.)

The pattern shown in Figure IV-3 is unusual in that two isochrons have apparently been obtained for the same rock unit. The samples on the 740 m.yr. isochron have remained closed systems with respect to exchange of rubidium and strontium since that time, while those on the younger isochron became homogeneous in their Sr⁸⁷/Sr⁸⁶ ratios 240 m.yr. ago. No significant differences are recognized between the two groups of samples, except that R1-T-2, R1-1, R1-4, and R2-1 all have higher and more variable strontium concentrations when compared to the others. The remaining samples, in fact, are remarkably uniform in their strontium concentrations. However, samples R5-T, R5-2, and R6-1, which are from the Laforme Creek area, all lie on the older isochron, so the distinction based on strontium concentrations may be meaningful only for the samples collected along the Trans-Canada Highway.

Problems relating to the re-distribution of rubidium and strontium during metamorphism have been considered by Lanphere et al. (1963), Arriens et al. (1966), and Ryan and Blenkinsop (1971), among others. There is general agreement that during metamorphism, strontium-rich minerals such as epidote, apatite and plagioclase will gain radiogenic stron-



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tium from rubidium-rich, strontium-poor minerals such as the micas. In other words, strontium-rich minerals will experience an increase in their Sr⁸⁷/Sr⁸⁶ ratios, while strontium-poor minerals will have their ratios lowered. As long as no strontium is lost from the total rock system, under these conditions the rock will preserve its original age. It is suggested that this situation prevailed for the samples on the older isochron, a suggestion that rubidium-strontium analysis of the minerals could confirm. Samples R5-1 and R6-2 probably represent rocks which have lost radiogenic strontium and therefore have not remained closed systems.

For the younger samples, homogenization of Sr⁸⁷/Sr⁸⁶ ratios must have occurred. The process by which this happened is not clear, in part because rubidium-strontium analyses of the separate minerals are not available, but some possibilities can be considered. One of these is complete expulsion of radiogenic strontium from all samples, a possibility which can be discounted because the two isochrons have different initial ratios. Partial loss of radiogenic strontium is possible, but the likelihood of the samples losing just enough radiogenic strontium so that they were all left at the time of alteration with the same Sr^{\$7}/Sr^{\$6} ratio is not very high. It seems more likely that exchange of both common and radiogenic strontium occurred. In this connection, Ross (1968) has observed that the metamorphism was quite variable throughout the area, so it may have been intense enough in some parts to bring about homogenization of the Sr⁸⁷/Sr⁸⁶ ratios, perhaps

through recrystallization of the minerals.

IV-4 The Quesnel Lake gneiss

The Quesnel Lake gneiss represents another area which may be crystalline basement. The gneiss has been described by Campbell (1961, 1963), Campbell and Campbell (1970), and Fletcher (1972). It is exposed along the north shore of the east arm of Quesnel Lake (Figure IV-4), where it forms an elongate topographic ridge.

The structure of the gneiss, according to Fletcher (1972), is that of a tight antiform overturned to the southwest. Further deformation has caused warping and arching of the structure to produce the present outcrop pattern. The gneiss plunges beneath surrounding metasediments, to the northwest and southeast. Minor structures within the gneiss are concordant with those in the metasediments, indicating that the gneiss and metasediments have experienced the same deformational history. No structures pre-dating the earliest deformation of the metasediments have been found within the gneiss.

Campbell (1961, 1963) considered the gneiss to be an exotic body of unknown age, but later (1970) suggested that it could represent crystalline basement on which sediments were deposited prior to folding. Fletcher (1972) has discussed four possible origins for the gneiss. It may represent:





1) a metamorphosed Proterozoic sedimentary unit.

2) basement exposed in the core of an anticline.

3) basement thrust into overlying sediments.

4) a metamorphosed igneous intrusion.

Fletcher has excluded the first possibility on chemical and petrographic grounds, and because no similar unit has been recognized elsewhere within the Kaza Group. Of those remaining, he discounts the second and third hypotheses because both would require an extra period of deformation, for which no evidence is observed. However, he considers that these hypotheses can be no means be completely excluded.

In support of his preferred interpretation, that the gneiss represents a metamorphosed igneous intrusion, Fletcher (1972) cites the following evidence: regionally metamorphosed skarns at the gneiss-metasediment contact; aplite dikes in the gneiss and metasediments; mafic inclusions within the gneiss which could be xenoliths; and the igneous trend of the chemical analyses. All of these points suggest intrusion of the gneiss into the sediments.

Thus, two different modes of origin for the gneiss are suggested - that it represents an igneous intrusion into Windermere sediments, or that it is crystalline basement upon which these sediments were deposited.

The writer of this thesis collected, with the assistance of C.J.N. Fletcher, a suite of samples from the Quesnel Lake gneiss. The isotopic results for these samples,

obtained with the techniques already described, are given in Table IV-3. An isochron (Figure IV-5) based on the indicated samples has an age of 740 ± 150 m.yr.

TABLE IV-3

Rubidium-strontium measurements of the Quesnel Lake gneiss.

Sample	Rb (ppm)	Sr (ppm)	Rb ⁸⁷ /Sr ⁸⁶	<u>Sr⁸⁷/Sr⁸⁶</u>
1F71	117	448	0.756	0.7121
2F71	133	321	1.20	0.7158
2AF71	143	338	1.23	0.7161
2BF71	142	459	0.896	0.7142
3F71	126	327	1.12	0.7156
4F71	140	581	0.698	017110
5F71	109	521	0.606	0.7097
8AF71 *	94.6	307	0.892	0.7058
18F71 *	8	490	0.05	0.7148
18AF71*	91.9	395	0.674	0.7127
20F71	107	363	0.854	0.7120

*Not used for isochron calculation

The two samples from the eastern end of the gneiss, 18F71 and 18AF71 were not used to determine the isochron because they came from an extensive zone of pegmatites. Sample 8AF71, which was also excluded, was from the contact between the gneiss and the metasediments. The significance of the age and the initial Sr^{87}/Sr^{86} ratio of .7033 ± .0020 will be discussed in the next chapter.

IV-5 The Malton gneiss

Giovanella (1968) described the Malton gneiss (Figure IV-6), a gneissic terrain straddling the Rocky Mountain Trench,



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as "a heterogeneous assemblage of layered gneisses and schists which range in composition from leucogranite to amphibolite." Rocks of the late Precambrian Kaza Group occur structurally above and to the south of the gneiss on the west side of the Trench. The gneiss on the east side of the Trench is surrounded by Cambrian quartzites (Gog Group) and late Precambrian schists (Miette Group). The Miette and Kaza Groups are regarded as equivalent. Giovanella (1968) considers that the gneiss is older than the enclosing sediments, and is also allochthonous.

Samples of the gneiss and schists for a rubidiumstrontium age study were collected by C. A. Giovanella, and made available to the writer through the kindness of R. K. Wanless of the Geological Survey of Canada. Preliminary attempts by the Geological Survey at dating the samples were inconclusive. From Giovanella's field descriptions, the writer grouped the samples according to lithological similarities, but only two groups contained more than two samples. The analyses of these samples are given in Table IV-4, and they are plotted on Figure IV-7. From the graph it is apparent that the points scatter about a rather poor isochron; its age was calculated to be 680 ± 80 m.yr. The estimate of precision of the age is not considered reliable for reasons to be discussed later, although the age itself is probably a valid estimate.

	RUDI	dium-strontium	measurements	or the Malto	n gneiss.
Samp	<u>le</u>	<u>Rb (ppm)</u>	Sr (ppm)	Rb ⁸⁷ /Sr ⁸⁶	<u>Sr⁸⁷/Sr⁸⁶</u>
401 -	8	47.9	49.0	2.84	0.7335
401-	9	70.6	55.8	3.68	0.7499
401-	10 *	20	138	0.420	0.7197
401-	11	109	156	2.03	0.7304
401-	12	70.2	41.4	4.93	0.7560
401-	13	48.5	302	0.465	0.7137
401-	14	82.2	319	0.747	0.7156
401-	17	100	245	1.18	0.7198

TABLE

*Not used for isochron calculation

IV-6 Calculation of isochrons

In a recent paper, Brooks et al. (1972) have reviewed the problem of isochron calculation, and in particular the estimation of errors. The authors proposed that the term "isochron" be restricted to those cases in which the data points fit the line within experimental precision. They propose the term "errorchron" for instances in which the scatter about the line exceeds experimental error. They point out that in the latter case, the estimate of age and initial ratio may still be valid, but the estimates of errors are probably poor. By their criteria, the two Revelstoke lines are isochrons, but the Quesnel Lake and Malton lines are errorchrons. The calculated uncertainties for the latter should be viewed with caution.

The slopes and intercepts were all calculated from the method proposed by York (1969). Following a suggestion by Brooks et al. (1972), the errors in Rb⁸⁷/Sr⁸⁶ and Sr⁸⁷/Sr⁸⁶







were considered to be uncorrelated. For the errorchrons, the uncertainties in age and initial ratio are based on the fit of the points to the line, and take no account of experimental uncertainties, which would make the estimates lower. For the isochrons, uncertainties are estimated by taking experimental uncertainties into consideration, the procedure recommended by Brooks et al. (1972).

The significance of these findings will be discussed in the next chapter.
CHAPTER V

CONCLUSIONS

V-1 Ages of the gneisses and their implications

The results obtained in this study are summarized below:

Area	Initial Ratio	Age (m.yr.)
Revelstoke	.7044 ± .0007 .7095 ± .0009	740 ± 30 240 ± 30
Quesnel Lake	$.7033 \pm .0020$	740 ± 150
Malton Range	.7086 ± .0014	680 ± 80

It is apparent that each area was affected by an event about 700 m.yr. ago. It will be recalled from the previous chapter that Ross's hypothesis implies that the gneisses are older than their enclosing sediments. The oldest sediments known to be involved in the deformation of the southern part of the Omineca Crystalline Belt are those of the Windermere sequence of age 600-800 m.yr. (Gabrielse, 1972). On a regional basis, therefore, these gneisses and the oldest sediments are indistinguishable in age, so that the age data alone neither support nor refute Ross's hypothesis.

In the original paper, Ross (1968) proposed that the oldest sediments present at Revelstoke were those of the Windermere Horsethief Creek Group. More recently, however, he has concluded that the metasediments surrounding the gneiss belong to the middle Hamill Group (Ross, personal communication, 1971), which is Lower Cambrian, i.e., post Windermere. Wheeler (1963) has made a similar observation. If these conclusions are correct, the gneiss at Revelstoke is demonstrably older than the enclosing sediments, and the age data are consistent with the hypothesis that the gneiss was tectonically emplaced into the sediments. Thus, at least at Revelstoke, Ross's hypothesis can be defended, although the gneiss is apparently not of Hudsonian age (1600-1800 m.yr.).

It is possible that the age of the gneiss represents a metamorphic age, in which case the arguments presented here are only strengthened. The rather low initial ratio of 0.7044 ± .0007 for the gneiss indicates, however, that the body is probably an intrusion, and that the date represents the time of intrusion. The low initial ratio does not preclude the possibility of the age being metamorphic, but any metamorphism would have had to result in quite complete expulsion of radiogenic strontium from the rock unit.

The age relationships, together with the structural data, are therefore seen to be consistent with the mode of dome formation proposed by Ross. His hypothesis will have to be modified slightly in that the gneiss is probably not Hudsonian (1600-1800 m.yr.) in age. If the gneiss at Revelstoke and the gneiss in the cores of the domes are equivalent, as appears quite likely, then the age data present serious problems for the model proposed by Reesor and Moore (1971), since they consider that the core gneisses were derived from

Windermere sediments at some time after the Permian. The gneiss is older than this, however, and the low initial ratio for the isochron is not compatible with derivation of the gneiss from sediments, at least by any simple process.

The results for the other two areas are less conclusive. The Quesnel Lake gneiss appears to be about the same age as the Windermere sediments which surround the gneiss (Fletcher, 1972). Fletcher considers it to be an intrusion into the Windermere Kaza Group, an interpretation which is supported by the low initial ratio of $0.7033 \pm .0020$. Campbell and Campbell (1970) describe the gneiss as crystalline basement upon which the sediments were deposited. The similarity in age of gneiss and metasediments make it impossible to choose between these alternatives on the basis of the geochronological data.

The age obtained for the Malton gneiss must be regarded with caution in view of the considerable scatter of points about the isochron. Nonetheless, the age is consistent with that of the other gneisses. Again, the gneiss is about the same age as some of its enclosing sediments, but is probably older than the quartzites of the Gog Group. The gneiss is generally regarded as allochthonous, and the age is certainly consistent with this interpretation, in that the late Precambrian gneiss and Kaza sediments surround the Lower Cambrian Gog quartzites.

V-2 Regional considerations

It seems reasonable to suggest that all areas were affected by the same event. It may therefore be possible to correlate this 700 m.yr. event with the East Kootenay Orogeny, which was first described by White (1959). He cited the presence of a regional unconformity between the Windermere and Belt-Purcell sediments as evidence for orogeny, and some mild folding and tilting of the Belt-Purcell rocks. From this and other evidence, the East Kootenay Orogeny is usually regarded as post Belt-Purcell, but pre-Windermere.

Approximate limits for the time of the East Kootenay Orogeny can be obtained from the maximum age of the Windermere sediments. An age of about 850 m.yr. (Obradovich and Peterman, 1968) for the youngest formations of the Belt-Purcell Supergroup is an upper bound for the time of orogeny. A minimum age cannot be determined from the Windermere sediments, because they are not fossiliferous, but they are overlain, in places conformably, by Lower Cambrian rocks. The deposition of the Windermere was accordingly completed about 600 m.yr. ago, but no estimate can be made of the time it started. The orogeny must be older than 600 m.yr., but younger than 850 m.yr.

Geochronological data from several sources suggest a time between 700 and 800 m.yr. for the East Kootenay Orogeny. Several potassium-argon ages of metamorphism believed associated with the orogeny fall within that range (Goldich et al., 1959; Leech, 1962; Leech, 1967). Similar ages were obtained for stocks thought to be intruded during the orogeny, but one

of them has since been dated by the rubidium-strontium method, and was shown to have an age of 1300 ± 100 m.yr. (Ryan and Blenkinsop, 1971). It is therefore not clear whether any intrusion accompanied the orogeny.

The proposal that the event observed in the gneisses correlates with the East Kootenay Orogeny is thus seen to be consistent with independent geological and geochronological evidence. If the correlation is valid, then the orogeny appears to be more extensive than previously thought. The contemporaneous Racklan Orogeny (Gabrielse, 1967, 1972) affected Purcell-equivalent rocks in northern British Columbia and the Yukon, and it is possible that both are evidence for a much larger event.

Fletcher's interpretation of the Quesnel Lake gneiss as an intrusive into Windermere sediments casts doubt on the correlation of the 700 m.yr. event with the East Kootenay Orogeny because the orogeny is considered pre-Windermere. Aalto (1971) argues for an initial orogeny, which was pre-Windermere, followed by periods of uplift during sedimentation. Perhaps the Quesnel Lake gneiss was emplaced during one of the later events.

It seems quite possible that the East Kootenay Orogeny encompassed multiple events extending over a considerable period of time, perhaps of the order of 100 m.yr. A similar situation has prevailed more recently in British Columbia in the interval from about 50 to 250 m.yr. ago. Accepting this interpretation, the orogeny probably began

about 800 m.yr. ago with uplift that led to the regional unconformity between the Belt-Purcell and Windermere sediments, and continued during the accumulation of Windermere sediments.

V-3 Timing of the Shuswap metamorphism

The 240 ± 30 m.yr. isochron for the Revelstoke gneiss requires some caution in interpretation. Until mineral data confirm the age, or more whole rock data are obtained, the isochron should be regarded as provisional. Nevertheless, the isochron is well determined, and it is tempting to regard the age as significant. It presumably reflects the time of maximum metamorphism. The age is consistent with the estimates by Ross and Kellerhals (1968) and by Reesor and Moore (1971) for the age of Shuswap metamorphism.

V-4 Relationship to plate tectonics

Papers presenting geological histories of British Columbia in terms of plate tectonic theory are only now starting to appear (Dercourt, 1972; Monger et al., in press), and perhaps it is premature to link the results obtained in this study to these ideas. Nonetheless, it is interesting to note that a subduction zone is thought to have existed in the region during Permian and/or Triassic time (Monger et al., in press), which would provide a mechanism for intrusion, metamorphism and thrusting within that time span. The 240 m.yr. age could, therefore, be related to subduction.

A subduction zone may also have existed during the

late Precambrian (Monger et al., in press). The gneisses may have been emplaced as intrusions while subduction was occurring, so the 700 m.yr. event may date the time of subduction. It is interesting to observe that the Atlantic may have been opening at about the same time (Dietz, 1972).

V-5 Summary

It will be recalled from Chapter I that the major aims of this study were twofold. The first purpose was to improve the precision of measurement of Sr^{87}/Sr^{86} ratios as a means of extending the variety of problems that can be studied by rubidium-strontium geochronology. To this end, a precision of 0.02% (95% confidence limit) has been achieved on a routine basis, primarily by means of an on-line data acquisition system for the mass spectrometer. The system has been used to obtain ages for suites of samples which have a range in Sr^{87}/Sr^{86} ratios of only about 1%, in contrast with a spread of 5% or more for most isochrons in the literature. If the Sr^{87}/Sr^{86} ratios for the younger Revelstoke isochron had been measured to a precision of 0.1%, the age determined would be 240 ± 110 m.yr., which has an unacceptably large uncertainty.

The second purpose of this study was to determine the ages of certain gneisses within the southern Omineca Crystalline Belt of British Columbia in order to determine if any were Precambrian in age. All three areas gave ages of about 700 m.yr. (late Precambrian), a result which lead to

possible correlation with the East Kootenay Orogeny. The data are consistent, at least in the Revelstoke area, with the hypothesis proposed by Ross (1968, 1970), so that it appears quite possible that Precambrian crystalline rocks were involved in the deformation, though these rocks do not appear to be Hudsonian in age.

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APPENDIX A-1

The determination of the half-life of the rubidiumstrontium decay scheme is obviously important in obtaining absolute ages. However, although the maximum energy of the β particles emitted by Rb⁸⁷ is 275 keV, their average value is only about 45 keV, so that difficulties are encountered in measuring the half-life by direct counting methods. Nonetheless, numerous attempts have been made to use direct counting, one of the more successful being by Flynn and Glendenin (1959), who obtained a value of 4.7 × 10¹⁰ yr. ± 2%. Their value is used in many laboratories today.

An alternative method has been to compare age determinations by different methods on the same samples. Aldrich et al. (1956) measured uranium-lead and rubidiumstrontium ages on several samples, and concluded that a halflife of 5.0×10^{10} yr. provided the best agreement between the ages. Kulp and Engels (1963) compared potassium-argon and rubidium-strontium ages for a group of minerals, and concluded that a half-life of 4.7×10^{10} yr. provided the best concordance between the ages. The value of 5.0×10^{10} yr. obtained by Aldrich et al. is also widely used today.

A third method of determining the half-life was reported by McMullen et al. (1966). They measured the accumulation of Sr^{87} produced in a rubidium salt over a known period of time. Their value for the half-life is 4.72×10^{10} yr. The value used in this thesis is 4.7×10^{10} yr., with an accompanying decay constant λ of 1.47×10^{-11} yr.⁻¹. This value was chosen largely because two different methods, direct counting and direct measurement, gave the same result, and the result is not inconsistent with that obtained by geologic comparison. The latter method, though, suffers from the problem of deciding whether or not the rubidium-strontium, potassium-argon, and uranium-lead methods are all dating precisely the same event. Certainly in the case of a sample which has cooled slowly, the retention of radiogenic argon is not likely to occur until long after the other "clocks" have started.

All rubidium-strontium ages referred to in this thesis have been re-calculated to a λ of 1.47 × 10⁻¹¹ yr.⁻¹ where necessary.

APPENDIX A-2

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Listing of Computer Program

*	STRONTIUM	ISOTOPE PRO	GRAM	VERSIO	ON 15/0	7/71
₩ ★	TNITTALTZE	ROUTINE				
*		ROOTIND				
	ORG	X 180 1				
	LPSW	*+4	HALT	COMPUTI	ER	
	DC	X *8000 *				
	DC	A (* +2)				
	LHI	3,H'13'				
	BAL	15,DISPL	ZERO	DISPLAY	ľ	
	DC	A (ZERO)				
	XHR	14,14				
	LHI	15,GO				
	STM	14,X*0044*	SET U	P INTER	RUPT	
	STH	14, TAPEWR+	Z RESE	T TAPEN	NR	
	111 CMU	14, <u>X'48ZF'</u>				
	STH	14, TAPEWR				
	201 201	14 A 4 1 C V				
	11 TC 17 TC	14 FCALC				
		14 PREND2				
	STH	14, PRSW+2				
	LHI	8.8181	DEVIC	E NO. C	F TAPE	DRIVE
	BAL	15.0UPT	IDENT	IFY PRO	OGRAM	
	DC	A (MESSO)				
	DC	н•54•				
	LHI	12,4	INITI	ALIZE S	SOME CO	UNTERS
	STH	12,L1				
	STH	12,L3				
	STH	12,L4				
	LHI	12,H'20'				
	STH	12,L2				
	XHR	11,11	ZERO	ID		
	LHI	12,1D				
		13, H'Z'				
		14, 10 END				
	BAI E	11,0(12) 12 本一川				
	BALL	15 01107	ACK T	ም ጥለወም		
		A (MPSS11)		I INCU	OULEUT	DESTURD
		H1281				
	BAT.	15. INPT	GET F	EPLY		
	DC	A (BTEMP)	ο μη μ	، مساعد معرف شد م		
L3	DC	H+4+				
_0	LH	4.BTEMP				
	CLHI	4,X*4E4F*	IS RE	EPLY INC)'?	
	BNE	TSTAT	NO, I	T ISN'I	ſ	

•

	LHI STH	9,X 430F 4 9.TAPEWR	SET 'TAPEWR' TO SKIP TAPE WRITE
	LHT	9.X 100041	
	STH	$9_{TAPEWR+2}$	
	LHT	9. 142001	· · · · · ·
	STH	9.STOP+8	
	B	SPIKE	
ጥናጥልጥ	SSR	8.0	STATUS OF TAPE DRIVE
10111	BFC	9.REW	BRANCH IF TAPE DRIVE READY
	BAL	15.0UPT	OUTPUT MESSAGE IF NOT
	DC	A (MESS1)	
	DC	H1221	
	LPSW	*+4	STOP COMPUTER
	00	X+C000+	STOL CONFOLDE
	DC	A (TSTAT)	
RPN	тнт	0×100201	
11.12.14	008	8 0	REWIND TAPE
	BAL	15.0UPT	ASK TE ETRST SAMPLE ON TAPE
		A (MPSS2)	ASK II TIKST SAULDE ON TALE
	DC	HINNI	
	BAL.	15. TNPT	GET RESPONSE
		A (RTEMD)	CEL VESTOREE
τ.1	DC		
<u></u>	I.H	4 BTEMP	
	CLHT	4,010HL	TS TT INCI ?
	BNE	*+8	TE INO! SEARCH FOR
	BAL	15.SKIP	2 CONSECUTIVE EOF'S
SPIKE	BAL	15.0UPT	ASK IF SAMPLE SPIKED
	DC	A (MESS12)	
	DC	H1221	
	BAL	15, INPT	GET REPLY
	DC	A (BTEMP)	
L 4	DC	ніч і	
	LH	5,BTEMP	
	CLHI	5,X'4E4F'	IS IT 'NO' ?
	BE	ASKID	
*	LHI	5,X*4200*	SUPPRESS NORMALIZATION IF SAMPLE
	STH	5.FCALC	
	LHT	4.PREND1	
	STH	4.PRSW+2	
ASKID	BAL	15.0UPT	ASK FOR I.D.
	DC	A (MESS3)	
	DC	H 1241	
	BAL	15, INPT	GET IT
	DC	A(ID+1)	• ·
L2	DC	н•20•	
	LH	5,*-2	FIND LENGTH OF ID
	AHI	5,1	
	LHI	4,X*0027*	DELIMITING CHARACTER
	STB	4,ID	
	STB	4, ID (5)	

		Appendix A-2 Program Listing
	BAL	ACTON
	DC	
	00 000	
	228 2778	
	BTC	
	BAL	
	DC	A (MESSU)
	DC	H 128 1
	XHR	12.12 ZERO SOME VARIABLES
	STH	12. CHECKPT
	STH	12.NPTS
	STH	12,SW
	STH	12, PTR1
	STH	12,PTR2
	STH	12,PTR3
	STH	12,NSCAN
	STH	12, TOTAL
	LHI	13, PTR
	LHI	14,2
	LHI	15, BEND
	STH	12,0(13) ZERO BUFFER
	BXLE	13 , $\mp \sim 4$
		12 PARTO1-4
		15 PP0107-2
	201 201	12, 0.012 = 2
	BAIL	13 * -1
	LHT	12.XIU2001 INTUTALTZE SWITCHES
	STH	12.CNTRI.
	STH	12.BASES
	STH	12, MAXMUM
WAIT	LPSW	*+4 WAIT FOR INTERRUPT
	DC	X * C000 *
	DC	A (*-6)
*		
ZERO	DC	3X 13030 1
MESSO	DC	X 8DO AO AO A
	DC	C * *** STRONTIUM ISOTOPE PROGRAM
MDCC11	DC	CVERSION B-/1 ***
HE2211		Δ'ΟDUA' CITS πλρφ ομφρμφ οφοτρφοί
		VISTAPE COLOI DESIRED.
MESS12		
100012	DC	CITS SAMPLE SPIKED!
	DC	X '8DO A8D3F'
MESS1	DC	X '8 DO A '
•	DC	C'PLEASE READY TAPE '
MESS2	DC	X *8D0 A *
	DC	C'IS THIS THE FIRST SAMPLE ON THIS TAPE '
	DC	X '8D0 A8D3F'
MESS3	DC	X * 8 D O A *

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.

MESS4 BTEMP ID IDEND * STOP	DC DC DC DC DC DC DC DC DC DC EQU LPSW DC	C * PLEASE E X * 8DO A 8D3F X * 8DO A * C * THANKS. X * 492 74 D2 0 C * ALL READ X * 8DO AO AO A 6C 6X * 00000000 *-2 *+ 4 X * 0000 *	NTER I.D. ' ' Y ' O' DISABLE INTERRUPT
	DC	A (*+2)	
	BAL	15,EOF	WRITE EOF'S AND REWIND TAPE
	LPSW	*+4	HALT COMPUTER
	DC	X 80000080	1
*		0000000000	
* INTI	SKRUPT	SERVICING	ROUTINE
*	сли	O CAUD	CTADE ATT DECTATEDE
90	ATR	3 U	STORE ALL REGISTERS
	CLHT	3, 8181	TAPE DRIVE PROBLEMS ?
	BE	TPERR	YES !
	CLHI	3, H'13'	RB-SR MASS SPECTROMETER ?
	BNE	END	NO, RETURN TO NORMAL PROCESSING
	LHI	1,1	LOOK FOR 'END RUN' INDICATION
	R DR	1,0	READ DISPLAY PANEL
	NHR	1,0	SW 15 SET ?
	BNZ	STOP	YES, PREPARE TO TERMINATE RUN
	LH	1,NPTS	INCREMENT RAW POINT COUNTER
	AHI	1,1	
	STH	1,NPTS	
DDTM	DAL		READ HASS SPECTROMETER
NDIN DSU	DG DG	n u	DVH READING (BINARI)
SCANB	FOI	*-1	
JUAND	LB	6.SCANB	GET SCAN BYTE
	LH	5.RBIN	GET NEW POINT
	LBR	7.6	LOAD SCAN BYTE
	NHI	7,X'0007'	STRIP OFF SCANNING INDICATION
	CLHI	1,2	FIRST POINT ?
	BL	*+12	YES, NO PREVIOUS SHUNT TO COMPARE
	CLH	7,LAST	COMPARE SHUNT TO PREVIOUS
	BE	CHECK	NO SHUNT CHANGE
	STH	7,LAST	STORE NEW SHUNT
	STH	1, RESET	STORE NO. OF RAW POINTS
	LH	4,SW	SET SWITCH TO INDICATE SHUNT CHANGE
		4,X'0001"	
CURCY	STH	4,5W	
CHECK	ST CTHT	I,KESET	ר א שר ספר א פוז א
	CUNT	1 / 1 / 1 / 1	O V TO TODET DM P

	Appendix A-	2 Program Listing
BL	*+16	NO, BRANCH
	4,SW	YES, RESET SW
NHL	4,X UUFE	
	4,5W 15 CNMDT	
DAL	10,CAIRL	CO TO SCAN RALE CONTROL ROUTINE
BBC	J # +8	NO BRANCH
ріс	5,8100001	VES. ADD 10000
BAL	15.FILTER	GO TO FILTER CALLING ROUTINE
STH	5.FILPT	STORE FILTERED POINT
BAL	15.SIBTOD	CONVERT TO DECIMAL
DC	A (FILPT)	
DC	A (BUFF1)	
LB	7, CBYTE+1	MOVE SCAN BYTES
STB	7,CBYTE	
LB	7,CBYTE+2	
STB	7,CBYTE+1	
STB	6,CBYTE+2	
LB	6,CBYTE	
	4,SW	IS SW ON ?
	4,X'0001'	NO DDANCH
D2 ТВ	CRSW 6 SCANB	NU, DAANGA VRS SO FIII CRYME NITME NEW RYME
םם. מידי א	6 CRYTE	THO, SO TILL COILE WITH NEW DILL
STB	6.CBYTE+1	
STB	6.CBYTE+2	
OHI	6.X'0080'	AND FLAG SCAN BYTE TO
STB	6,SCANB	INDICATE SW ON
CRSW BAL	15, SWITCH	OUTPUT TO DISPLAY
В	STATUS	CONTINUE
END LM	0,SAVR	RESTORE REGISTERS
LPSW	X • 0040 •	RETURN TO NORMAL PROCESSING
*		
CBYTE DS	28	
NPTS DS	H	
LAST DS	n u	
LESET DS	п भ	
	н	
BUFF1 DS	6C	
SAVR DS	16H	
*		
* SCAN RAT	E CONTROL RO	UTINE
*		
CNTRL BTC	O,HERE	NORMALLY BRANCH TO 'HERE'
STH	5, PREV	EXECUTE THIS SEQUENCE AT START
LB	4,FAST	OF EACH SCAN
51'B 1 UT		БЕТ КАТЕ ТО ГАБТ Сре сиррі ситеси
LUT Cun	7,Δ'43VU' Ο ("ΝΠΟΤ	SET CHIRE SWIFCE
חוכ מתמוו	7.68186	
<u> </u>	9.50	CHECK SW

.

	BZ LHI STH BR LHR SH STH BP BM	*+14 9,X *4200* 9,CNTRL 15 9,5 9,PREV 5,PREV PLUS MINUS	BRANCH IF SW OFF RESET CNTRL SWIFCH EXIT R5 CONTAINS NEW POINT R9 CONTAINS CHANGE IN DVM READING CHECK SIGN OF DIFFERENCE
RTRN	LH SH CLHI BL LB STB OC WD BR	0,NPTS 0,CHECKPT 0,H'80' *+12 0,FAST 0,RATE 3,SPEED 3,RATE 15	SPEED SET TO 'FAST' 16 SECS. AFTER PEAK IS DETECTED SET FOR SCAN RATE CONTROL
*			
PLUS	CLH BL LB CLHI BL LH AHI STH LH STH CLHI BNL LB STB B LB STB B B	9, CRIT RTRN 4, RATE 4, 4 RTRN 4, NPK 4, 1 4, NPK 0, NPTS 0, CHECKPT 4, 2 * + 16 4, MED 4, RATE RTRN 4, SLOW 4, RATE RTRN	IS DIFFERENCE SIGNIFICANT ? NO WAS RATE SET TO 'FAST' ? NO, PEAK ALREADY DETECTED YES, SO FIND POSITION IN SPECTRUM NPK IS NO. OF PEAKS SO FAR STORE TIME OF SPEED CHANGE PAST 1ST PEAK - SPEED SHOULD BE SLOW SPEED SHOULD BE MEDIUM SET RATE SET SPEED TO SLOW
MINIC	VUT	O VIPEPPI	
U T N U 2	AHI CLH BL LB STB B	9,1 9,CRIT RTRN 4,FAST 4,RATE RTRN	IS DIFFERENCE SIGNIFICANT ? NO SET RATE TO FAST
*			
FAST MED SLOW NPK RATE CRIT	DC DC EQU DS DS DC	X '0403' X '0201' *-1 H H H'50'	

PREV	DS	Н	
CHECKPT	DS	H	
*			
* ROU1	CINE TO	D CHECK STAT	TUS BYTE
*			
STATUS	LH	8,SW	CHECK SW
	NHI	8,X'0001'	
	ΒZ	*+10	BRANCH IF OFF
	XHR	5,5	STORE ZERO IN BUFFER IF SW ON
	В	STORE	
	LBR	7,6	GET SCAN BYTE
	NHI	7,X'0007'	SET UP SHUNT FOR INDEXING
	AHR	7,7	
	SHI	7.2	
	LH	8.CRUDE (7)	GET CRUDE BASE
	BNZ	*+8	IF ZERO. THIS POINT IS CRUDE BASE
	STH	5. CRUDE (7)	SO STORE IT
	SH	5, CRIDE (7)	SUBTRACT CRUDE BASE
	тит	15 STORE	SET RIS FOR RETURN FROM STORF
	TRD	7 6	CHECK SCAN CHARACTER
		7 7 100701	SCANNING 2
	NHI BN7	*+20	VPC BDANCH
		1 2112001	NO CO PREPT CHTRI AND RCAIC
	CULT	1 CMMDT	SUITTCHES AND BOANCH TO BASES
	STU	1 + 10	SWITCHES AND BRANCH IO BRSES
		DACTC	
	D	DADED	PTDCM NON-DACRIENE DOTM
	BFC	0,*+24	FIRST NON-BASELINE POINT
	BAL	15, BUALC	CAUSES BRANCH TO 'BCALC'
	LH1	1, X 4300	THEN BUALC SWITCH IS RESET
	STH	1,*-12	
	LHI	1,X 4200	AND MAXMUM SWITCH IS INITIALIZED
	STH	1, MAXMUM	
	LHI	15, STORE	
	CLHI	7,X'0070'	CHECK FOR SCAN REJECT
	BE	REJECT	REJECT FOUND - REJECT SCAN
	CLHI	7,X'0030'	CHECK FOR END OF SCAN
	BE	EOS	END OF SCAN FOUND
	В	MAXMUM	OTHERWISE GO TO MAXMUM
*			
* REJI	ECT ROU	JTINE	
*			
REJECT	STH	15,RTEMPO	
	BAL	15,DISPL	WRITE ZERO ON DISPLAY
	DC	A (ZERO)	
	LH	15, RTEMPO	
	LHI	7,X'8000'	INDICATE REJECT
	STH	7,BOUT	
	0C	3, SPEED	SET SCAN SPEED TO FAST
	WD	3.FAST	· · · · · · · · · · · · · · · · · · ·
	LH	7.5	SET SW
	OHT	7. 100081	
	STH	7.50	
		· · · · ·	

BR 15 CONTINUE	
*	
* ROUTINE TO SEARCH FOR MAXIMA	
MAXMUM BTC O, NORM NORMALLY BRANCH PAST FOLLO	WING
XHR 11.11 INSTRUCTIONS	
LHI 12.WRK	
LHI 13.2	
LHI 14.COUNT	
STH 11.0(12) ZERO MAXMUM WORK AREA	
BXLE 12.*-4	
LHI 10.X'4300'	
STH 10.MAXMUM SET MAXMUM SWITCH	
NORM LH 10.COUNT INCREMENT COUNT	
AHI 10.1	
STH 10.COUNT	
XHR 8,8	
LH 11, CRNT+4 (8) MOVE POINTS IN CRNT BUFF	ER
STH 11, CRNT (8)	
LH 11, CRNT+6 (8)	`
STH 11, CRNT+2 (8)	
AHI 8,4	
CLHI 8, H'16'	
BL *-24 BRANCH IF NOT ALL MOVED	
STH 5, CRNT+16 ADD NEWEST POINT	
STH 6, CRNT+18 AND SCAN BYTE	
LH 9,CRNT+8	
AH 9,CRNT+12 ADD LAST THREE POINTS	
AHR 9,5	
STH 9, WRK+8 STORE SUM IN WORK AREA	
CLHI 10,5 IF < 5 POINTS, SKIP MAXIMU	M CHECK
BL SHIFT	
LH 10, NFPTS R10 CONTAINS TIME	
MAXI XHR 4,4	
LH 8, WRK+4 GET POINT TO BE TESTED	
LHR 13,8 (CENTRE POINT OF FIVE)	
SH 13, WRK (4) SUBTRACT ONE OF THE OTHER	POINTS
$\begin{array}{cccc} BM & SHIFT & IF < U_{\mu} & NU & MAXIMUM \\ BMG & ++12 & CENTRE DOTME > OTHER DOTME$	
DNZ ++12 CENTRE POINT > OTHER POINT	mureo
CLOI 4,4 IF POINTS ARE EQUAL, AND U BNI CHIET DOINT COMES ARTED CENTER D	
	UTNI,
CLHI 4,2 DRANCH CLHI 4,4 DON'T COMPARE POINT WITH I BF *-8	TSELF!
CLHI 4,2 DRANCH CLHI 4,4 DON'T COMPARE POINT WITH I BE *-8 CLHI 4.10 DONE 2	TSELF!
CLHI 4,2 DRANCH CLHI 4,4 DON'T COMPARE POINT WITH 1 BE *-8 CLHI 4,10 DONE ? BI MAXI+6 NO SO BRANCH	TSELF!
CLHI 4,2 DRANCH CLHI 4,4 DON'T COMPARE POINT WITH 1 BE *-8 CLHI 4,10 DONE ? BL MAXI+6 NO, SO BRANCH B YES FOUND & MAXIMUM!	TSELF!
Ani 4,2 BRANCH CLHI 4,4 DON'T COMPARE POINT WITH I BE *-8 CLHI 4,10 DONE ? BL MAXI+6 NO, SO BRANCH B YES FOUND A MAXIMUM! *	TSELF!
Ani 4,2 BRANCH CLHI 4,4 DON'T COMPARE POINT WITH I BE *-8 CLHI 4,10 DONE ? BL MAXI+6 NO, SO BRANCH B YES FOUND A MAXIMUM! * SHIFT XHR 4.4	TSELF!
<pre>Ani 4,2 BRANCH CLHI 4,4 DON'T COMPARE POINT WITH 1 BE *-8 CLHI 4,10 DONE ? BL MAXI+6 NO, SO BRANCH B YES FOUND A MAXIMUM! * SHIFT XHR 4,4 LH 7.WRK+2(4)</pre>	TS EL F !

	AHI CLHI BL	4,2 4,8 SHIFT+2	ALL DONE ? NO, CONTINUE
т.	BR	15	BRANCH TO STORE
¥ Yes	LH CLH	9,NMAX 9,XS SUIDE	GET MAXIMA COUNTER OVERFLOW TABLE ?
	XHR LHI	11,11 12,4	ILS, SU SKIP II
		14,-10000	
MAXLP	LH	1, CRNT (11)	SEARCH FOR MAXIMUM OF THE THREE
	SHR	1,14	SUBTRACT PREVIOUS MAXIMUM
	BM LH	4+10 14.CRNT(11)	THIS POINT BIGGER
	LHR	2,11	STORE MAXIMUM POINTER
	BXLE	11, MAXLP	
	LH	11, CRNT+2 (2	2) GET SCAN BYTE OF MAXIMUM
	STВ лнр	11, SHMAX (9)	AND STORE IT
		11.CRNT (2)	GET POINT ITSELF AND
	STH	11, MAX (9)	STORE
	SRHA	2,2	
	AHI	10,-3(2)	
	STH	10, 1MAX(9)	STORE TIME OF MAXIMUM
	AHI	9.1	INCREMENT COUNTER
	STH	9.NMAX	
	B	SHIFT	PREPARE TO EXII
* VC	DC	81221	
M B K Y D		п•32• 5н	
CRNT	DS	10H	
COUNT	DS	Н	
* *			
* CAL	N ROUT.	INE FOR SCAL	N PROCESSING
EOS	LPSW	*+4	ENABLE INTERRUPT
	DC	X 4000	
	DC	A (* +2)	
	STH	15, RTEMPO	
	BAL	15,DISPL	ZERO DISPLAY
	LH	A (ZERU) 15 RTEMPO	
	LH	8.NFPTS	CARRY-OVER FROM PREVIOUS SCAN ?
	CLHI	8,H'10'	
	BNL	*+10	NO, SO BRANCH
	NHI	6,X'008F'	YES, REMOVE EOS INDICATION
	DK T.H	10 10 9 10	
	OHI	9,X'0080'	SHI ON TO ENDERTH DED OF DOAN

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	1	Appendix A-2	? Program Listing
	CMH	0 01	
	STH		
	BAL	15, STURE	BRANCH TO STORE
	LI CMU	9, TUTAL	
	5TD	9, TUTALZ	
		0 NIPIS	
	AUA CTU		INCREMENT TOTAL FOINT COUNTER
	AHD	8 8 PIOINT	CIEND CEDMAIN COUNTEDS
	C TT LL	S NDTC	CLEAR CERTAIN COUNTERS
	AHD	11 11	
	ፍሞዝ ርሞዝ	11 NFDTS	
	STH		
	ант	8 2	
	CLHT	8,10	
	RT	*-12	
	I.HT	9. 12.	RESET SOME SWITCHES
	STH	9 CNTRL	KIDDI DOUL DATIONDD
	STH	9.BASES	
	STH	9.MAXMUM	
	LH	8.SW	SKIP PROCESSING IF SCAN REJECTED
	NHT	8.X 100081	
	BNZ	*+32	
	BAL	15.REFINE	SUBTRACTS TRUE BASELINES
	BAL	15, PEAK	PICKS PEAKS
	BAL	15, CALC	CALCULATES RATIOS
	BAL	15, CONVRT	PREPARE FOR PEAK PRINTOUT
	LH	8,NSCAN	INCREMENT SCAN NO.
	AHI	8,1	
	STH	8,NSCAN	
	XHR	8,8	
	LHI	9,NMAX	
	LHI	10,2	
	LHI	11,BOUT-2	
	STH	8,0(9)	ZERO MAXIMUM TABLE
	BXLE	9,*-4	
	LH	8,SW	
	LHR	9,8	R8 AND R9 CONTAIN SW
	NHI	8,X*0007*	REMOVE REJECT INDICATION FROM SW
	STH	8,SW	
	NHI	9,X 0008	IF SCAN WAS REJECTED, NO RATIOS
	BNZ	WAIT	TO OUTPUT
FUALC	BAL	15, FRACT	CALCULATE NORMALIZED SR87/SR86
	В	PRINT	PRINT SCAN SUMMARY
*	nc	t)	
TUTAL	בע סמ	ก บ	
TUTALZ NCCAN	כע	n u	
NACAN	S	11	
	י הי דא די	ר אייי אייי	TITES
* "		J SIURE DASE	
BASES	BT C	A RYDASS	SKTD FOLLOWING SECTION TE NOT
ᆕᇥᆇᇣᇦ	XHR	11.11	FIRST CALL
		· · · · ·	

	i	Appendix A-2	2 Program Listing
	тит	1ጋ ጥምጠጋ	7 PDA BASFITNF MATDIY
	LHT	13.2	ZERO DASELINE MAIRIX
	LHI	14.BASE+8	
	STH	11,0(12)	
	BXLE	12,*-4	
	LHI	7,X*4300*	SET SWITCH
	STH	7,BASES	
BYPASS	LH	0,NFPTS	
	LBR	7,6	
	NHL	7,X'000/	GET SHUNT AND ADJUST
	AHK	1,1	FOR ADDRESSING
	5nL TH	I J L NBASE (7)	ANV DOINTS ON THIS SHINT VET 2
	BN7	*+12	VEC SKID
	STH	0.FTRST(7)	NO. SO STORE TIME
-	B	*+16	
	LHR	1,0	CHECK THAT POINTS ARE CONSECUTIVE
	SH	1, TEMP (7)	
	CLHI	1,1	
	BNER	15	EXIT IF THEY AREN'T
	STH	0, TEMP (7)	
	CLHI	4, H'50'	>50 POINTS ON THIS BASE ?
	BNLR	15	YES, SO RETURN
	AHL	4,1 // NDNCR(7)	
	STH	4,NDASE(/) 1 5	INCREMENT NEASE
	лн Три	1,J 1 BASP (7)	እስከ ሮሀንያፑለጥ ወሰናለጥ ጥሰ ጥሰጥእና
	STH	1. BASE (7)	FOR THIS SHUNF
	BR	15	GO TO 'STORE'
*			
TEMP	DS	5 H	
FIRST	DS	5 H	
NBASE	DS	5H	
BASE	DS	58	
* 2011			DACRETANDO
*	CINE IV	J CALCULATE	DASELINES
BCALC	XHR	4.4	
201120	STH	4 NPK	ZERO NPK IN CNTRL
	LH	2, NBASE(4)	GET NO. OF BASELINE POINTS
	BNZ	*+18	IF ZERO, NO POINTS ON THIS SHUNT
	AHI	4,2	、
	CLHI	4,8*10*	
	BNLR	15	EXIT POINT
	B	BCALC+6	TRY ANOTHER SHUNT
	XHR	8,8	CALCULADE CORDECTION
	Сриу ГЦК	1,2	CALCULATE CURRECTION
	алла т и	G BASP (II)	CRT SUM OF DOINTS
	BNM	フォロムコニ(4) 本+1社	SKTP TE NUMBER DOSTTIVE
	LHT	8.X FFFFF	GENERATE 32 BIT NEGATIVE NUMBER
	SHR	9,1	
	SHR	9,1	GENERALE SZ DEL NEGALIVE NUMBER

Appendix A-2 Program Listing В *+6 AHR 9,1 DHR 8,2 DIVIDE SUM BY NUMBER OF POINTS 1, FIRST (4) CALCULATE TIME FOR POINT AH 7. X 100201 DETERMINE WHICH PART OF SCAN CLHI BNE *+12 LHI 8.BHD SCANNING DOWN *+20 В *+12 BNL LHI 8.BLO SCANNING UP В *+8 LHI 8,BHU END OF SCAN SLHA 4.1 AHR 8,4 CALCULATE WHERE TO STORE RESULT SRHA 4,1 LH 10,2(8) SOMETHING ALREADY THERE ? BNZ *+12 YES, SO DON'T STORE THESE NUMBERS STH 9,0(8) STORE AVERAGED POINT STH STORE TIME 1,2(8) XHR 2,2 STH ZERO BASE AND NBASE FOR 2, BASE (4) THIS SHUNT STH 2, NBASE(4)STH 2, FIRST (4) ALSO ZERO FIRST В BCALC+14 DO ANOTHER SHUNT * * ROUTINE TO STORE FILTERED POINTS * STORE 2,NFPTS INCREMENT FILTERED POINT COUNTER LH AHI 2,1 STH 2,NFPTS 7.PTR GET INDICATOR LH STH 5, BOUT(7)STORE POINT IN OUTPUT BUFFER STH 6,BOUT+2(7) STORE SCAN BYTE 7,4 INCREMENT INDICATOR AHI 7,PTR STH LHR 8.7 LH 7,SW 7,X'0080' NHI IS EOS BIT ON ? *+12 YES, OUTPUT RECORD BNZ CLHI 8.H'256' 64 POINTS ? BL END NO, RETURN TO NORMAL PROCESSING STH 15, RTEMP1 YES, SO OUTPUT RECORD BAL 15, TAPEWR DC A (BOUT) DC A (BEND) 15, RTEMP1 LH XHR 1,1 1.PTR STH ZERO INDICATOR LHR 7,7 WAS SW ON ? BNZR 15 YES, RETURN В END RETURN TO NORMAL PROCESSING

*

*	ROUTINE	TO OUTPUT RAT	FIOS, ETC ON TELETYPE
*			
PRINT	C BAL	15,SIBTOD	CONVERT SCAN NO. TO ASCII
	DC	A (NSCAN)	
	DC	A (BTEMP)	
	LH	1,BTEMP+4	LOAD NO. OF SCANS (MAX. OF 99)
	STH	1, PROUT+14	STORE IN PRINT OUTPUT AREA
	LHI	3, PROUT	
	LH	4, PREND	
	LHI	2,2	
	SSR	2,0	CHECK STATUS OF TELETYPE
	BTC	1,WAIT	EXIT IF TELETYPE POWERED DOWN
	00	2,WRT	SET WRITE MODE
TSENS	S SSR	2,0	
	BTC	8, TSENS	LOOP IF TELETYPE BUSY
	WD	2,0(3)	OUTPUT A BYTE
	AHI	3,1	
	CLHE	R 3,4	ALL DONE ?
	BL	TSENS	NO
PRSW	CLH	4, PREND2	
	BE	WAIT	
	CLH	4, PREND1	
	BE	*+16	
	LHI	3, PROUT1	
	LH	4, PREND1	
	В	TSENS	OUTPUT SECOND PRINT BUFFER
	LHI	3, PROUT2	
	LH	4, PREND2	
	В	TSENS	OUTPUT THIRD PRINT BUFFER
*			
WRT	DC	X *9898*	
*			
*	ROUTINE	TO GENERATE	OUTPUT BUFFER
*			
CONVE	T STH	15, RTEMP2	
	LH	12, NPEAKS	R12 CONTAINS NO. OF PEAKS FOUND
	AHR	12,12	
	SHI	12,1	ADJUST R12 FOR ADDRESSING
	XHR	2,2	
	LHI	13, HTS	
	LHI	11,X*8D0A*	
*			
CONLE	LB	8, POINT (2)	GET POINTER BYTE
	LH	7, IMAX (8)	GET TIME OF MAXIMUM
	AH	7, TOTAL2	CALCULATE TIME FROM START OF RUN
	STH	7, BTEMP	
	STH	13, WHERE	ADDRESS OF ASCII NUMBER
	LHI	14,*+8	RETURN ADDRESS
	B	CONV	CONVERT TIME TO ASCII
	LH	7, MAX (8)	GET MAXIMUM
	STH	7,BTEMP	
	AHI	13,8	

	STH LHT	13, WHERE INCREMENTED ADDRESS OF ASCII NUMBER
	B	CONV CONVERT PEAK HEIGHT TO ASCII
	LHR	7,8
	LB	8, POINT (12) GET POINTER FOR UPMASS SECTION
	CLHR	1,8 DONE UPMASS AND DOWNMASS PEAK ?
	DE NHT	
	B	CONTP+4
CONV	BAL	15.SIBTOD
	DC	A (BTENP)
WHERE	DS	Н
	BR	14
	AHI	13,6
*	STH	11,0(13) INSERT CARRIAGE RETURN/LINE FEED
*	лчт	ΙΝΤΟ ΤΕΧΤ 13.6 ΝΠΊΚΩ ΡΈΩΤΩ ΤΡΟ ΤΟ ΝΈΥΤ ΡΈλΚ
	ΔΗΤ	2.1
	SHI	12.1
	CLHR	2,12 PEAKS ALL DONE ?
	BL	CONLP NO, MORE PEAKS TO DO
	SHI	13,4
	STH	13, PREND STORE ENDING ADDRESS OF FIRST
	LH	15, RTEMP2 BUFFER
*	DR	
PROUT	DC	X *8 D0 A *
	DC	C'SCAN NUMBER '
	DS	Н
	DC	X *8D0 A 8D0 A *
	DC	C' PEAK DATA: '
	DC	
HTTS	DC	907120201
	DC	X * 8 DO A *
1 40 0 1 1	DC	C' RATIOS: '
·	DC	X * 8 DO A *
	DS	2H
RATIO1	DS	120
RATIO2	DS	120
RATIO3	פת	120
PROUT2	DC	X 18 DO A 1
1 10012	DC	C' NORMALIZED RATIO: '
NRATIO	DC	4x • 20 20 •
	DC	X *8 D0 A *
PREND	DS	H .
PREND1	DS	H
PREND2	DS	Н
* 0.11	סם יידונייו	MUTINE FOR MACHEWIC WADE
÷ ∪0.	TEAT WA	UTINE FOR HAGNEILC THEE

,

TAPEWR	LH STH LH STH LHI OC	2,0(15) 2,X'0000' 2,2(15) 2,X'0002' 2,8 2,TWRT	GET STARTING ADDRESS AND STORE GET ENDING ADDRESS AND STORE DEVICE NUMBER OF TAPE DRIVE OUTPUT RECORD
*	В	4 (15)	RETURN
TWRT WEF *	DC EQU	X 4802 *-1	
EOF	LHI SSR BTC OC SSR BTC OC LHI SSR BTC OCR	2,8 2,0 8,*-2 2,WEF 2,0 8,*-2 2,WEF 1,X'0020' 2,0 8,*-2 2,1	DEVICE NUMBER OF TAPE DRIVE DEVICE BUSY ? YES, WAIT WRITE AN END OF FILE WAIT AGAIN WRITE ANOTHER REWIND COMMAND BYTE REWIND TAPE
*	DK	10	REIORN
* 20111	• • • • • • • • • • • • • • • • • • •	א תא שבוור מא	TMA FOR BASETINE DRIFT
*		ADDODI GRA	THE TOK DESIGN DELT
REFINE	STH STH XHR LHI	3,RTEMP2 15,RTEMP3 1,1 7,DELTD	SAVE R3 AND R15 ZERO WORK AREA
	LHI LHI STH BXLE	8,2 9,CORR+18 1,0(7) 7,*-4	
	LHI LHI LHI XHR	14,DELTD 10,BHD 11,BLO 4,4	ADDRESS FOR STORING RESULTS ADDRESS OF FIRST SET OF BASELINES ADDRESS OF SECOND SET
SLOOP	LHR AHR LHR AHR LHR AHR	12,10 12,4 13,11 13,4 15,14 15,4	SET UP REGISTERS FOR ADDRESSING
	LH BZ STH LH BZ SHR SHR	7,2(12) NONE 7,TIMES(1) 8,2(13) NONE 8,7 8,2(15)	GET TIME OF FIRST SET NO POINTS ON THIS SHUNT STORE TIME OF SET GET TIME OF SECOND SET IF ZERO, TROUBLE ! FIND DELTA T STORE IT
	LH	7,0(12)	GET BASELINE VALUE FOR FIRST SET

NONE	STH LH SHR STH AHI	7,CORR(1) 8,0(13) 8,7 8,0(15) 1,2	GET OTHER BASELINE VALUE FIND DELTA H STORE IT
	AHI	4,4	
	CLHI	4, H*20*	ALL SHUNTS DONE ?
	BL	SLOOP	NO, CONTINUE
		14,DELTU	DONE BOTH BLOCKS ?
	BE		
	THP THT	14,DELTU	SET UP TO DO UPMASS BLJCK
	14 1		
	B	SL00P-2	GO AROUND AGATN
*	2	51001 2	SO RROOMD RONAN
SFIN	XHR	11.11	
	LHI	12, IMAX	SET UP REGISTERS FOR PEAK HEIGHT
	LHI	13, MAX	ADJUSTMENT
	LHI	14, SHMAX	
MORE	LHR	8,12	
	AHR	8,11	R8 IS TIME POINTER
	LHR	9,13	
	AHR	9,11	R9 IS HEIGHT POINTER
	SRHA	11,1	
	LHR	10,14	DAA TO GOAN DUND DOTNOD
	AHR	10,11	RIU IS SCAN BILE POINTER
	ADK TP	$11_{0}11$	ሮፑጥ ድሃጣም
	NHT	7 8 100071	CRT SHINT
	BZ		ZERO SHUNT MEANS ALL PRAKS DONE
	AHR	7.7	
	SHI	7,2	USE SHUNT FOR ADDRESSING
	LH	6,0(8)	GET TIME FOR MAXIMUM
	CLH	6,TIMES+10	(7) COMPARE TO TIME AT CENTRE OF SCAN
	BNL	*+14	IF GREATER, WANT UPMASS BLOCK
	XHR	0,0	
	LHI	4,DELTD	IF LESS, WANT DOWNMASS BLOCK
	8	*+12	
	101		FLAG RO TO INDICATE BLOCK
	унь Гцт		
	AHR	4.7	ADJUST POINTER
	LH	3.2(4)	GET DELTA T FOR BASELINES
	BZ	NOBASE	NO BASELINES FOR THIS MAXIMUM !
	LHR	0,0	SET CONDITION CODE
	BNZ	*+12	GET TIME OF RIGHT BLOCK
	SH	6,TIMES(7)	CALCULATE DELTA T FOR MAXIMUM
	В	*+8	
	SH	6,TIMES+10	(7)
	LHR	3,6	
	MH	2,0(4)	CALCULATING ADJUSTMENT
	LH	6,2(4)	ROUND-OFF FACTOR

	SRHA	6,1	
	LHR	2.2	CHECK SIGN OF PRODUCT
	BNM	*+14	POSITIVE
	SHR	3.6	NEGATIVE
	SCH	2 NTL	
	B C II	* 10	
		+ · IV	
	АНК	3,0	
	ACH	2,NIL	
	DH	2,2(4)	CALCULATE ADJUSPMENT
	LHR	0,0	
	BNZ	*+12	
	AH	3, CORR (7)	CALCULATE CORRECTION
	В	*+8	
	AH	3, CORR+10 (7	1)
	LH	1.0 (9)	GET MAXIMUM
	SHR	1.3	APPLY CORRECTION
	STH	1 0 /91	
	AUT	11 2	REFORM IT TO HARTHOU TABLE
	Ant		MODE DOTHER TO DO
DIN	B	NORE	NURE POINTS TO DO
DUN	LH 	3, RTEMP2	RESTORE REGISTERS
	LH	15, RTEMP3	
	BR	15	EXIT
*			
NOBASE	LH	7,SW	NO BASELINES FOR A PEAK, SO
	OHI	7, X '0008'	REJECT SCAN AND FLAG IT
	STH	7.SW	
	LH	3.RTEMP2	RESTORE REGISTERS
	I.H	15.RTEMP3	
	R	24(15)	SKTD SCAN DROCESSING
*	U	24(15)	SKII SCAN LAOCHSSING
	DC	5 0	
	05	51 E 10	
DELTO	D2	107	
TIMES	D2	IUH AOU	
CORR	DS	TOH	
*			
* ROUT	PINE TO	DIDENTIFY F	PEAKS, AND ADJUST FOR GROWTH OR
* DECA	Υ.Υ.		
*			
PEAK	XHR	10,10	
	STH	10, NPEAKS	ZERO NPEAKS
	LH	9.NMAX	
	ΒZ	ERRET	NO MAXIMA !
	AHR	9.9	
	YHR	2 2	
	VHD	1 1	
MATOD		1/1 7 M3V/101	
HAJOR		7, ELAA (10)	GET A MAXIMUM
		**12	
	CLHI	/,H*25*	BIG ENOUGH ?
	BNL	OK	YES
	AHI	10,2	NO
	CLHR	10,9	DONE ALL MAXIMA ?
	BL	MAJOR	

	В	DONE	YES
OK	STB	10, POINT (2)	STORE MAXIMUM POINTER
	LH	0, IMAX (10)	GET TIME OF MAXIMUM
	SHR	0.1	FIND TIME DIFFERENCE FROM
	T.H	1. TMAX (10)	PREVIOUS MAXIMUM
	CLHT	0 H1181	LIGVIDOD HARHON
	DI	FTV	THO MAYTMA ON ONE DEAK I
			INO HAAIHA ON ONE PEAK :
	Anı		ALL OK
	LH	4, NPEAKS	INCREMENT NPEAKS
	AHI	4,1	
	STH	4,NPEAKS	
	В	MAJOR+16	CONTINUE
FIX	LHR	4,2	
	SHI	4,1	R4 NOW POINTS TO PREVIOUS MAXIMUM
	LB	8, POINT (4)	
	CLH	7.MAX (8)	COMPARE THE MAXIMA
	BI.	MAJOR+16	PREVIOUS MAXIMUM IS BEST
	BE	MAJOR+16	
	SUB		ICE NEU MAYTMIM
	D D T D	MA TOPA16	USE NEW HAAINON
*	D	HAJUKTIO	
T	* **	10 NDBARC	
DONE		IZ, NPCAKS	GET NUMBER OF PEAKS
	82 35.55	ERRET	NO PEAKS !
	SRHA	12,1	DIVIDE BY TWO
	BFC	8,*+20	EVEN NO. OF PEAKS
ERRET	LH	9,SW	SET SW FOR REJECT -
	OHI	9,X'0008'	ERROR HAS OCCURRED
	STH	9,SW	
	В	20 (15)	SKIP REST OF PROCESSING
	STH	12,NPEAKS	
	AHR	12,12	
	SHI	12,1	
	LB	8,POINT+2	GET POINTERS FOR SR86 PEAK. R8 FOR
	LB	9. POINT-2 (1	2) DOWNMASS PEAK, R9 FOR UPMASS
	LH	13. TMAX (8)	
	ΔH	13. TMAY (9)	
	AHT	13 1	
	CDUN	13,1	D12 HOTDS TIME FOD SDG DEAK
	CDUN	0 1	AIS HOLDS THE FOR SROO PEAK
	ANAC		
		3, 5 HHAX (0)	RS CONTAINS SHONT FOR SR86 PEAK
	NHL	3, 1000/	
	XHR	11,11	
	XHK	2,2	
PLOOP	LB	8, POINT (2)	
	LB	9, POINT (12)	
	LH	5, MAX (8)	GET DOWNMASS PEAK HEIGHT
	LH	7,MAX (9)	GET UPMASS PEAK HEIGHT
	SRHA	8,1	
	SRHA	9,1	
	LB	0, SHMAX (8)	GET CORRESPONDING SHUNT BYTES
	LB	1. SHMAX (9)	
	AHR	8.8	
	** ** **		

AHR	9,9	
NHI	0,X'0007'	REMOVE SCANNING INDICATION
NHI	1,X'0007'	
SHR	1,0	COMPARE BYTES
ΒZ	ADD	PEAKS ON SAME SHUNT
AHR	1,1	PEAKS ON DIFFERENT SHUNTS
BNM	ADD-4	UPMASS PEAK ON HIGHER SHUNT
LH	14, FACT (1)	GET SUITABLE SHUNT FACTOR
SRHA	14,1	THESE INSTRUCTIONS ADJUST PEAKS
AHR	7,14	TO SAME SHUNT
LH	14, FACT (1)	
XHR	6,6	
DHR	6,14	
В	A D D	
MH	6, FACT (1)	
CLHI	2,2	
BE	SR86	BRANCH IF DOING SR86 PEAK
SHR	7,5	FIND HEIGHT DIFFFRENCE BETWEEN PEAKS
LH	4, IMAX (8)	TIME OF DOWNMASS PEAK
LH	1,IMAX (9)	TIME OF UPMASS PEAK
SHR	1,4	FIND TIME DIFFERENCE
LHR	14,13	TIME OF SR86 PEAK
SHR	14,4	TIME DIFFERENCE FROM SR86 PEAK
MHR	6,14	CALCULATE ADJUSTMENT
LHR	4,1	
SRHA	4,1	
LHR	6,6	
BNM	*+14	
SHR	1,4	
SCH	D ,NLL	
B	*+10 7 /	
АПК		
	6 1	
	57	
VHD		ADJUST FERK HEIGHT
LHR	1.0	
SHR	1.3	COMPARE PEAK SHINT WITH SR86 SHINT
BZ	STPKS	PEAKS ON SAME SHUNT
AHR	1.1	PEAKS ON DIFFERENT SHUNTS - ADJUST
BNM	SR86-8	TO SR86 SHUNT
LH	14, FACT (1)	PEAK ON LOWER SHUNT
LHR	1,14	
SRHA	1,1	
AHR	5,1	
DHR	4,14	
XHR	4,4	
В	STPKS	
MH	4, FACT (1)	PEAK ON HIGHER SHUNT
В	STPKS	
AHR	5,7	CALCULATE SR86 PEAK HEIGHT
AHI	5,1	

ADD

,

	SRHA	5,1	
	XHR	4,4	
STPKS	STH	4, PEAKS (11)	STORE PEAK HEIGHT (32 BITS)
	STH	5, PEAKS+2 (11)
	AHL	11,4	
	Anl	2,1	
		12_{1}	DONE ALL DEAVE 3
	BT	2,12 PI 00P	DONE ALL PEARS :
	88	15	RU, GO ROOMD ROAIN
*	DR	15	
POINT	DS	10C	
PEAKS	DS	5F	
NPEAKS	DS	H	
	DC	H'81'	
	DC	H 1271	
	DC	H • 9 •	
	DC	H131	
FACT	DC	H11	
	DC	H 131	
	DC	H+9 •	
	DC	H*27*	
- 4 -	DC	H•81•	
* POURT	LNE CV1	CHITAMPS TO	
* TO 2	LNE CAI	COLVIDO TO	DIOPE RALIOS AND CONVERIS THEN
*	AD CI I		
* CALC	STH	15,RTEMP5	
* CALC	STH LHI	15,RTEMP5 13,RATIO1-4	BLANK RATIO OUTPUT AREA
* CALC	STH LHI LHI	15,RTEMP5 13,RATIO1-4 14,2	BLANK RATIO OUTPUT AREA
* CALC	STH LHI LHI LHI	15,RTEMP5 13,RATIO1-4 14,2 15,PROUT2-2	BLANK RATIO OUTPUT AREA
* CALC	STH LHI LHI LHI LHI	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X * 2020*	BLANK RATIO OUTPUT AREA
* CALC	STH LHI LHI LHI LHI STH	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X '2020' 12,0 (13)	BLANK RATIO OUTPUT AREA
* CALC	STH LHI LHI LHI STH BXLE	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12,X * 2020* 12,0 (13) 13,*-4	BLANK RATIO OUTPUT AREA
* CALC	STH LHI LHI LHI LHI STH BXLE LHI	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X * 2020* 12,0 (13) 13,*-4 14, PEAKS	BLANK RATIO OUTPUT AREA
* CALC	STH LHI LHI LHI STH BXLE LHI LH	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X * 2020* 12,0 (13) 13,*-4 14, PEAKS 13, 10 (14)	GET SR86 PEAK
* CALC	STH LHI LHI LHI STH BXLE LHI LH LHR SPHA	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X ' 2020' 12,0 (13) 13,*-4 14, PEAKS 13, 10 (14) 7, 13 7, 1	BLANK RATIO OUTPUT AREA 2 GET SR86 PEAK ADJUSTMENT FOR ROUNDING
* CALC	STH LHI LHI LHI STH BXLE LHI LH LHR SRHA LHT	15, RTEMP5 13, RATIO1-4 14, 2 15, PROUT2-2 12, X * 2020* 12, 0 (13) 13, *-4 14, PEAKS 13, 10 (14) 7, 13 7, 1 12, RATIO1	GET SR86 PEAK ADJUSTMENT FOR ROUNDING
* CALC	STH LHI LHI LHI STH BXLE LHI LHR SRHA LHI XHR	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X '2020' 12,0 (13) 13,*-4 14, PEAKS 13, 10 (14) 7,13 7,1 12, RATIO1 6,6	GET SR86 PEAK ADJUSTMENT FOR ROUNDING ADDRESS OF OUTPUT AREA
* CALC	STH LHI LHI LHI STH BXLE LHI LHR SRHA LHI XHR LH	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X ' 2020' 12,0 (13) 13,*-4 14, PEAKS 13, 10 (14) 7,13 7,1 12, RATIO1 6,6 11, NPEAKS	GET SR86 PEAK ADJUSTMENT FOR ROUNDING ADDRESS OF OUTPUT AREA R11 IS LOOP COUNTER
* CALC	STH LHI LHI LHI STH BXLE LHI LHR SRHA LHI XHR LH SHI	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X ' 2020' 12,0 (13) 13,*-4 14, PEAKS 13, 10 (14) 7,13 7,1 12, RATIO1 6,6 11, NPEAKS 11,1	GET SR86 PEAK ADJUSTMENT FOR ROUNDING ADDRESS OF OUTPUT AREA R11 IS LOOP COUNTER
* CALC AROUND	STH LHI LHI LHI STH BXLE LHI LH SRHA LHI XHR LHI SHI LH	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X * 2020* 12,0 (13) 13,*-4 14, PEAKS 13,10 (14) 7,13 7,1 12, RATIO1 6,6 11, NPEAKS 11,1 0,0 (14)	GET SR86 PEAK ADJUSTMENT FOR ROUNDING ADDRESS OF OUTPUT AREA R11 IS LOOP COUNTER GET PEAK HEIGHT
* CALC AROUND	STH LHI LHI LHI STH BXLE LHI LHR SRHA LHI XHR LHI SHI LH LH	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X ' 2020' 12,0 (13) 13,*-4 14, PEAKS 13,10 (14) 7,13 7,1 12, RATIO1 6,6 11, NPEAKS 11,1 0,0 (14) 1,2 (14)	GET SR86 PEAK ADJUSTMENT FOR ROUNDING ADDRESS OF OUTPUT AREA R11 IS LOOP COUNTER GET PEAK HEIGHT GET OTHER HALF
* CALC AROUND	STH LHI LHI LHI STH BXLE LHI LHR SRHA LHI XHR LH SHI LH LH LH LH LH R	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X ' 2020' 12,0 (13) 13,*-4 14, PEAKS 13, 10 (14) 7,13 7,1 12, RATIO1 6,6 11, NPEAKS 11,1 0,0 (14) 1,2 (14) 0,13	GET SR86 PEAK ADJUSTMENT FOR ROUNDING ADDRESS OF OUTPUT AREA R11 IS LOOP COUNTER GET PEAK HEIGHT GET OTHER HALF CALCULATE INTEGER PART OF RATIO
* CALC AROUND	STH LHI LHI LHI STH BXLE LHI LHR SRHA LHI XHR LH LH LH LH LH LH LH LHR	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X ' 2020' 12,0 (13) 13,*-4 14, PEAKS 13, 10 (14) 7,13 7,1 12, RATIO1 6,6 11, NPEAKS 11,1 0,0 (14) 1,2 (14) 0,13 3,0	GET SR86 PEAK ADJUSTMENT FOR ROUNDING ADDRESS OF OUTPUT AREA R11 IS LOOP COUNTER GET PEAK HEIGHT GET OTHER HALF CALCULATE INTEGER PART OF RATIO MOVE REMAINDER
* CALC AROUND	STH LHI LHI LHI STH BXLE LHI LH LHR SRHA LHI XHR LH SHI LH LH LH LH LHR CLHI	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X * 2020* 12,0 (13) 13,*-4 14, PEAKS 13, 10 (14) 7,13 7,1 12, RATIO1 6,6 11, NPEAKS 11,1 0,0 (14) 1,2 (14) 0,13 3,0 1,3	GET SR86 PEAK ADJUSTMENT FOR ROUNDING ADDRESS OF OUTPUT AREA R11 IS LOOP COUNTER GET PEAK HEIGHT GET OTHER HALF CALCULATE INTEGER PART OF RATIO MOVE REMAINDER INTEGER PART < 3 ?
* CALC AROUND	STH LHI LHI LHI STH BXLE LHI LHR SRHA LHI XHR LH SHI LH LH LH LHR CLHI BNL	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X ' 2020' 12,0 (13) 13,*-4 14, PEAKS 13,10 (14) 7,13 7,1 12, RATIO1 6,6 11, NPEAKS 11,1 0,0 (14) 1,2 (14) 0,13 3,0 1,3 *+16	GET SR86 PEAK ADJUSTMENT FOR ROUNDING ADDRESS OF OUTPUT AREA R11 IS LOOP COUNTER GET PEAK HEIGHT GET OTHER HALF CALCULATE INTEGER PART OF RATIO MOVE REMAINDER INTEGER PART < 3 ? NO
* CALC AROUND	STH LHI LHI LHI STH BXLE LHI LH LHR SRHA LHI XHR LH SHI LH LH LHR CLHI BNL LHI	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X ' 2020' 12,0 (13) 13,*-4 14, PEAKS 13, 10 (14) 7,13 7,1 12, RATIO1 6,6 11, NPEAKS 11,1 0,0 (14) 1,2 (14) 0,13 3,0 1,3 *+16 8,4	GET SR86 PEAK ADJUSTMENT FOR ROUNDING ADDRESS OF OUTPUT AREA R11 IS LOOP COUNTER GET PEAK HEIGHT GET OTHER HALF CALCULATE INTEGER PART OF RATIO MOVE REMAINDER INTEGER PART < 3 ? NO FOUR DECIMAL PLACES
* CALC AROUND	STH LHI LHI LHI STH BXLE LHI LHR SRHA LHI XHR LH SRHA LHI LH LHR LHR LHR LHR LHR LHR LHR LHR LHR	15, RTEMP5 13, RATIO1-4 14,2 15, PROUT2-2 12, X ' 2020' 12,0 (13) 13,*-4 14, PEAKS 13, 10 (14) 7,13 7,1 12, RATIO1 6,6 11, NPEAKS 11,1 0,0 (14) 1,2 (14) 0,13 3,0 1,3 *+16 8,4 4, TENM	GET SR86 PEAK ADJUSTMENT FOR ROUNDING ADDRESS OF OUTPUT AREA R11 IS LOOP COUNTER GET PEAK HEIGHT GET OTHER HALF CALCULATE INTEGER PART OF RATIO MOVE REMAINDER INTEGER PART < 3 ? NO FOUR DECIMAL PLACES SCALE FACTOR = 10000
* CALC AROUND	STH LHI LHI LHI STH BXLE LHI LH SRHA LHI XHR LH SRHA LHI XHR LH LH CLHI BNL LHI LH BNL	15, RTEMP5 13, RATIO1-4 14, 2 15, PROUT2-2 12, X ' 2020' 12, 0 (13) 13, *-4 14, PEAKS 13, 10 (14) 7, 13 7, 1 12, RATIO1 6, 6 11, NPEAKS 11, 1 0, 0 (14) 1, 2 (14) 0, 13 3, 0 1, 3 *+16 8, 4 4, TENM SCALE	GET SR86 PEAK ADJUSTMENT FOR ROUNDING ADDRESS OF OUTPUT AREA R11 IS LOOP COUNTER GET PEAK HEIGHT GET OTHER HALF CALCULATE INTEGER PART OF RATIO MOVE REMAINDER INTEGER PART < 3 ? NO FOUR DECIMAL PLACES SCALE FACTOR = 10000
	BNL	*+16	NO
-------	------------	--------------	--------------------------------------
	LHI	8,3	THREE DECIMAL PLACES
	LH	4.ONEM	SCALE FACTOR = 1000
	В	SCALE	
	CLHT	1. H! 300!	INTEGER PART < 300 ?
	BNI.	*+16	NO
	TUT	0 7	
	101 T U	U ONEC	1 WO DECLINE PEACES
	ьа	4, UNEC	SCALE FACTOR - 100
	B	SCALE	
	CLHT	1,H'3000'	INTEGER PART < 3000 ?
	BNL	*+16	NO
	LHI	8,1	ONE DECIMAL PLACE
	LH	4,TEN	SCALE FACTOR = 10
	В	SCALE	
	XHR	8,8	INTEGER PART > 3000 !
	В	*+18	SCALE FACTOR = 1 , SO SKIP SCALING
SCALE	MHR	0,4	SCALE INTEGER PART OF RATIO
	MHR	2.4	SCALE FRACTIONAL PART
	AHR	3.7	FOR ROUNDING
	ACH	2.NTL	
	DHR	2.13	CALCHLATE FRACTIONAL PART OF RATIO
	AHR	1 3	CALCOBATE FRACTIONAL FRAT OF ANTEO
	STH.	8 NDEC (6)	STORE NO OF DECEMAL DIACES
	STH STH	1 BIN	STORE NO. OF DECEMPE PERCES
	CULT		
	C m U	1, DRAII0(0)	STORE DIMARI RAILO
	DIT		
	DAL	15, SIBTUD	CONVERT RATIO TO DECIMAL NUMBER
		A (DIN)	ADDRESS OF ACCTT DARTS
		1 0 0	ADDRESS OF ASCIL RATID
	LHK	8,8	NO DESTUDI DOTVE
	BZ	NODEC	NO DECIMAL POINT
	LHK	10,12	
DLOOP	LB	9,5(10)	MOVE BYTES TO RIGHT OF DECIMAL
	CLHI	9,X 0020	A BLANK ?
	BNE	*+8	NO
	LHI	9,X'0030'	YES, REPLACE BY ZERO
	STB	9,6(10)	
	SHI	8,1	DECREMENT COUNTER
	BZ	*+12	MOVED ALL BYTES
	SHI	10,1	
	В	DLOOP	MORE TO MOVE
	LHI	9,X'002E'	A DECIMAL POINT
	STB	9,5(10)	
NODEC	AHI	14.4	
••••	CLHT	14. PEAKS+8	NO NEED TO CALCULATE
	RE	*-8	SR86/SR86 RATIO
	лнт	6.2	SROUY SROU RAILO
	ΔΗΤ	12 12	
	CUT	11 1	DONE ALL DEAKS 2
	DN7		NU TITE TUULO :
	THT THT	10 0 DUA	169
	SHI	12,2	

	STH	12, PREND1	ADDRESS OF BUFFER END
	STH	11,-2(12)	STORE CARRIAGE RETURN/LINE FEED
	LH	15, RTEMP5	
*	BR	15	YES, RETURN
ተ ጥ ዋ N	DC	H#10#	
ONEC		H 100 P	
ONEM		H 100	
TENM		HI10000	
RIN	20	н н	
BDATTO	פת	11 /1 II	
NDEC	D2 D2	4 11	
*	50	411	
* ROU	TINE	NORMALIZES S	R87/SR86
*			
FRACT	STH	15, RTEMP2	
	LHI	10,X'2020'	BLANK NRATIO AREA
	STH	10,NRATIO+	6
	LHI	10, 8375	ACCEPTED SR88/SR86 RATIO
	LHR	9,10	
	SH	9, BRATIO	SUBTRACT MEASURED SR88/SR86 RATIO
	MH	8,TENM	SCALE
	LHR	8,8	
	BM	*+14	ROUND-OFF PROCEDURE
	AHR	9,10	
	ACH	8,N1L	
	В	*+10	
	SHR	9,10	
	SCH	8,NIL	D.T.T.T.C.C.D.
	AHR	10,10	DIVISOR
	DHR	8,10	
		9, TENM 1 DDAMTO10	R9 CUNTAINS THE UNE-MASS FACTUR
		I, BRATIU+Z	GET SK87/SK86 KATIO
		1 8150001	AND NORMALIZE II
	ADI		HORE ROUND-OFF
	АСП		
	UN CMU	1 DDATTOLD	
		15 CTRMOD	
		1 J ST DIOD	CONVERI NORMALIZED RATIO IO ASCII
		A (DEATION)
	LH	8 NDEC+2	NUMBER OF DECEMAL PLACES
	BN7	DSHIFT	NOT ZERO, SO BRANCH
	LH	15.RTEMP2	EXIT POINT
	BR	15	UNIT FOINT
DSHIFT	LHI	10.NRATIO	
	LB	9.5(10)	MOVE BYTES TO RIGHT OF DECIMAL
	CLHI	9.X 0020	INSERT ZEROES TO RIGHT OF DECIMAL
	BNE	*+8	IF NEEDED
	LHI	9.X'0030'	
	STB	9.6(10)	
	SHI	8,1	LOOP COUNTER

.

	ΒZ	*+1 2	ALL DONE
	SHI	10,1	
	В	DSHIFT+4	CONTINUE
	LHI	9,X'002E'	DECIMAL POINT
	STB	9,5(10)	STORE IT IN NUMBER
	LHI	9,NRATIO+1	0
	STH	9 PREND2	ADDRESS OF BUFFER END
	В	DSHIFT-6	GO TO EXIT POINT
*			
* ROH	TTNE T	O READ MASS	SPECTROMETER
*			ST BOTTOURTER
READ	YHD	h h	
RUHD	тит	τ , τ 5 1	
		5,1	
	LUI		
		3,1N(4)	READ MASS SPECTROMETER
	RD	3, BUFF+2 (4))
	BXLE	4,*-8	LOOP TILL ALL READ
	STH	15,RTEMP4	
	BAL	15,SIDTOB	CONVERT DVM READING TO BINARY
	DC	A (BUFF)	
	DC	A(RBIN)	
	LH	15, RTEMP4	
	LB	2,BUFF+6	FORM SCAN BYTE
	LB	4.BUFF+7	
	SLHL	4.4	
	OHR	2.4	
	STB	2.3(15)	STORE IT
	LB	2 BUFF+8	CPT OUTDUT PROUPST SUITCH SETTING
	ርጥ B	2,001100	AND CUCIEDI UPACIOI DATICH DETITUR
	210	272(1J) 11115)	
*	D	4 (15)	KETURN
т Т N	DC	V 100001	
TN		X*0809*	
	DC	X TO AU B	
	DC	X OCOD	
	DC	X *0 E0 F *	
OUT	DC	X 100011	
	DC	X *0 20 3 *	
	DC	X 104051	
SPEED	DC	X 106071	
BUFF	DC	X 2B30	
	DS	8C	
*			
* ROU'	TTNE OI		IGTTAL DISPLAY
*			
DISDI	тя	1 0 (15)	
1. T. T. T.	тир	$\frac{1}{2} \left(\frac{1}{1} \right)$	REPRESS OF MOUDER TO BE OUTPUT
		2,1	ENDING ADDRESS
	ALT	4,0	ENDING ADDRESS
	XHK	4,4	
DISTL	гв	0,0(1)	GET BYTE TO BE DISPLAYED
	CLHI	0,X'002E'	IS IT A DECIMAL POINT ?
	BE	DECOUT	YES
	0C	3,0UT (4)	OUTPUT DIGIT

Appendix A-2 Program Listing SEND BYTE TO DISPLAY WDR 3.0 AHI 4,1 AHI 1,1 1,2 DONE ? CLHR NO. CONTINUE BL DISLP B 2(15) YES, RETURN DECOUT LHR 0,1 GET ADDRESS OF CURRENT BYTE CALCULATE DECADE FOR DECIMAL POINT SH 0,0(15)0C 3,0UT+5 WRITE DECIMAL POINT WDR 3,0 AHI 2,1 В DECOUT-14 CONTINUE * * ROUTINE DETERMINES DESIRED OUTPUT FOR DISPLAY * SWITCH STH 15, RTEMP6 LHI 7.DUMP 2.RSW GET SWITCH POSITION LB CLHI 2,1 IF 1, OUTPUT FILTERED POINT BNE *+20 LHI 4.5 OC 3,0UT+5 WDR 3,4 LHI 4, BUFF1+1 BR 7 CLHI 2.2 IF 2, OUTPUT FIRST RATIO *+10 BNE LHI 4, RATI01+1 BR 7 2,4 IF 4, OUTPUT SECOND RATIO CLHI BNE *+10 LHI 4, RATIO2 + 17 BR 2,5 IF 5, OUTPUT NORMALIZED RATIO CLHI *+10 BNE LHI 4, NRATIO+1 7 BR CLHI 2,6 IF 6, OUTPUT THIRD RATIO BNE *+10 LHI 4, RATIO3+1 7 BR IF 8, OUTPUT FOURTH RATIO CLHI 2,8 BNE *+10 LHI 4, RATIO4 + 1BR 7 4,ZERO LHI IF NONE OF ABOVE, OUTPUT ZERO DUMP STH 4,*+8 BAL 15, DISPL OUTPUT DESIRED INFORMATION DS Η LH 15, RTEMP6 15 RETURN BR

*

* FIL *	TER CA	LLING SUBRO	UTINE
FILTER	STH BAL DC DC DC DC	15,RTEMP7 15,FILT H'07' A(WSP1) A(WSP1+14)	SEVEN POINT FILFER
PTR1	DS	H UZU H	KEEP EVERI SECOND POINT
T	BAL DC DC DC	15,FILT H'03' A(WSP2) A(WSP2+6)	THREE POINT FILTER
PTR2	DC DS	H * 0 1 * H	KEEP ALL POINTS
-	BAL DC DC	15,FILT H º 05 º A (WSP3)	FIVE POINT FILTER
PTR3	DC DC DS	A (WSP3+10) H•02+ H	KEEP EVERY SECOND POINT
*	LH BR	15,RTEMP7 15	
₩SP1 WSP2 WSP3 *	DS DS DS	7н 3н 5н	,
* * FILT *	ER SUB	ROUTINE	
FILT	STM LH LH LH SHR LHR	0, SAVE1 11,0(15) 6,2(15) 3,4(15) 2,2 3,2 1,6	SAVE REGISTERS GET FILTER LENGTH GET ADDRESS OF WORK AREA AND ENDING ADDRESS
	LH NHI BZ STH	14,SW 14,1 NXT 5,0(1)	LOAD SW TEST FOR SHUNT CHANGE SW OFF SW ON - FILL BUFFER WITH NEW POINT
	BXLE B	1,*-4 *+20	SKIP MOVE OPERATION IF SW WAS SET
* N X T	LH STH AHR CLHR	0,2(1) 0,0(1) 1,2 1,3	MOVE POINTS IN WORK AREA

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	BL	NXT	
	STH	5,0(3)	STORE NEW POINT
	LH	9,8(15)	FILTER THIS TIME ?
	AHL	9,1	
	CI H	9,0(15)	
	BNE	FINISH	NO. SO SKIP CALCULATION
	XHR	4.4	YES
	STH	4,8(15)	
	АН	5,0(6)	ADD NEWEST AND OLDEST POINT
	AHI	5,1	
	SRHA	5,1	DIVIDE BY 2 (TAPERED ENDPOINTS)
	XHR	10,10	
LP	AHR	6,2	INCREMENT R6 BY 2
	SHR	3,2	DECREMENT R3 BY 2
		0,3 CONT	AKE THEI EQUAL : VEG ETIMEDING AIMOGT DONE
	лн	5 0 (6)	NO CONTINUE
	ACHR	4,10	ADD POINTS
	AH	5.0(3)	
	ACHR	4,10	
	В	LP	
CONT	AH	5,0(6)	ADD CENTRE POINT
	ACHR	4,10	
	LHR	9,11	R9 WILL CONTAIN DIVISOR
	SRHA	11,1	DIVIDE BY 2
	ACHD	5,11 // 10	AND ADD FOR ROUNDING
	SHT	9.1	R9 CONTAINS FILTER WEIGHT
	DHR	4.9	NORMALIZE POINT
	STH	5, SAVE1+10	STORE IT
	LM	0,SAVE1	RESTORE REGISTERS
	В	10 (15)	RETURN
*			
FINISH	LM	0,SAVE1	EXIT HERE IF FILTERING IS SKIPPED
	В	END	
ች ሮእፕሮ1	DC	160	
SAVE1	22	юп	
* BINARY	t TO/FI	ROM ASCII BO	CD CONVERSION ROUTINES
*	C m M	10 01 17	
SIBTOD		10,5AVE	SAVE REGISTERS
	лпл Т.Н	14.0(15)	A (ARGUMENT)
	LH	15,2(15)	A (RESULT)
	LHI	12.X'0020'	BLANK SIGN
	LH	13,0(14)	GET ARGUMENT
	STB	12,0(15)	STORE SIGN
	LHI	14,8	
FΒ	LH	11, TABLE-2	(14) GET DIVISOR
	XHR	12,12	
	DHR	12,11	

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	LHR	10,10	SET CONDITION CODE
	BNZ	*+18	SUPPRESS LEADING ZEROS
	LHR	10,13	LOAD RESULT INTO R10
	BNZ	*+12	NOT LEADING ZERO
	LHI	13,X'0020'	REPLACE LEADING ZERO WITH A BLANK
	В	*+8	
	OHI	13,X'0030'	ADD ASCII ZONE
	STB	13,1(15)	AND STORE CHARACTER
	LHR	13,12	GET REMAINDER
	AHI	15,1	INCREMENT POINTERS
	AHI	14,-2	
	BNZ	FB	
	OHI	12,X'0030'	GENERATE LAST CHARACTER
	STB	12,1(15)	
	LM	10,SAVE	RESTORE REGISTERS
	В	4 (15)	EXIT
SAVE	DS	6 H	
TABLE	DC	H • 10 •	
	DC	H !1 00 !	
	DC	H 1000 1	
	DC	H !10000!	
*			
SIDTOB	STM	10, SAVE	SAVE REGISTERS
	LH	14,0(15)	A (ARGUMENT)
	LHI	15,4(14)	END OF BCD NO.
	XHR	10,10	
	LHI	11,H•10•	MULTIPLIER
LOOPZ	LB	13,1(14)	GET FIRST DIGIT
	NHI	13,X 000F	REMOVE ZONE
	AHR	13,10	ADD RESULT
	MHR	12,11	* 10
		10,13	
	AHL	14,1	INCREMENT POINTER
		14,10	END IET:
	םם מד	12 1/141	NU, DRANUT CRM INCM DICIM
	NUT	13,1(14)	STAT TAST DIGIT
	NHP	10 13	
	LB	10, 15 12 - 4(14)	CFT SIGN
	NHT	12, 4(14) 12 81007F1	REMOVE RYTRA BIT
	CLHT	12,X 1002D	MINUS SIGN?
	BNE	*+12	NO. BRANCH
	XHT	10.X . FFFF.	TWO'S COMPLEMENT
	AHI	10.1	and the set of the fields shapened has been been as
	LH	15. SAVE+10	RESTORE R15
	LH	14,2(15)	GET A (RESULT)
	STH	10,0(14)	STORE RESULT
	LM	10, SAVE	RESTORE REGISTERS
	B	4 (15)	EXIT
*		. ,	
* TNDD	AND OF		

- *
- INPUT AND OUTPUT ROUTINES FOR TELETYPE

OUPT	STM LH LHR	12, SAVE 12, 0 (15) 13, 12	SAVE REGISTERS GET A(MESSAGE)
	AH	13.2(15)	ADD LENGTH AND
•	SHI	13.1	ADJUST FOR WE INSTRUCTION
	LHI	14.2	DEVICE NO. OF TELETYPE
	OC	14.BLOK	SET WRITE MODE
	WBR	14.12	OUTPUT MESSAGE
	LM	12.SAVE	RESTORE REGISTERS
	B	4(15)	RETIRN
*	2	11101	
INPT	STM	11.SAVE	STORE REGISTERS
	LH	12.0(15)	A (BUFFER)
	LHR	13.12	
	AH	13,2(15)	CALCULATE BUFFER END
	LHT	14.2	DEVICE NO. OF TELETYPE
	00	14. UNBL	SET READ MODE
SENSE	SSR	14.11	SENSE STATUS OF TELETYPE
01001	BTC	15. SENSE	BRANCH TE STATUS NOT ZERO
	R DR	14.11	READ ONE CHARACTER
	NHT	11.X 007F	STRTP EXTRA RTT
	CLHT	11.X'007F'	BUB-OUT CHARACTER?
	BE	DELLN	VES. BRANCH
	CT.HT	11.X.005F	DELETE LAST CHARACTER?
	BE	DELCH	YES. BRANCH
	CLH	12.0(15)	FTRST CHARACTER?
	BNE	*+12	NO. BRANCH
	CLHT	11. 100201	LEADING BLANK?
	BE	SENSE	YES. TGNORE IT
	CLHT	11.X'000D'	END OF TEXT INDICATED?
	BE	RET	YES, BRANCH
	STB	11.0(12)	STORE CHARACTER
	AHT	12.1	INCREMENT R12
	CLHR	12.13	END OF BUFFER?
	BI.	SENSE-4	NO. GET NEXT CHARACTER
RET	SH	12.0(15)	CALCULATE TEXT LENGTH
	STH	12.2(15)	STORE LENGTH IN CALLING PROGRAM
	0C	14.BLOK	SET WRITE MODE
	LHI	12.MS+1	
	LHI	13.MS+2	
	WBR	14,12	ADVANCE LINE AND RETURN CARRIAGE
	LM	11.SAVE	RESTORE REGISTERS
	В	4 (15)	RETURN
*			
DELLN	0C	14, BLOK	SET WRITE MODE
	LHI	12,MS	SET UP REGISTERS FOR WB
	LHI	13, MS+3	
	WBR	14,12	OUTPUT CONFIRMATION MESSAGE
	В	INPT+4	START AGAIN
*			
DELCH	SHI	12,1	DELETE LAST CHARACTER
	CLH	12,0(15)	WAS IT FIRST CHARACTER?

	BL	DELLN	YES BRANCH
	B	SENSE-4	NO, GET ANOTHER CHARACTER
*			
MS	DC	X 1 A 3 8 D 0 A 3 F	1
*	20		
BIOK	DC	V 10 Q X /1 1	
DLUK	DC	x · JOA4 ·	
	εQU	* -	
*			
*	ROUTINE	TO SEARCH TA	PE FOR TWO CONSECUTIVE FILE
×	MARKS		
*			
SKIP	XHR	7,7	
	STB	7,FILESW	FILESW INITIALLY ZERO
	LHI	1,1	
	LHI	6.X 100041	FORWARD SPACE COMMAND
AGATN	OCR	8.6	FORWARD SPACE ONE RECORD
	SSR	8 0	WATT TIL FINISHED
	877	8 *-2	RRANCH TE BUSV
	DIC		DIANGH IF DUSI DTID MADE DONNDI
	BIC	2,**!2	FILE MARK FOUND:
	STB	/,FILESW	RESET FILESW
	В	AGAIN	DO ANOTHER RECORD
	LB	0,FILESW	DETERMINE STATUS OF FILESW
	LHR	0,0	SET CONDITION CODE
	BNZ	FOUND	TWO CONSECUTIVE FILE MARKS
	STB	1,FILESW	SET FILESW ON - FILE MARK FOUND
	В	AGAIN	LOOK FOR ANOTHER
FOUND	LHI	6,X'0010'	BACKSPACE COMMAND
	OCR	8.6	BACKSPACE TAPE
	BR	15	
*			
FTLES	W DS	н	
*	. 20		
*		דה האתידרדה מ	ADR RAPODS
*	ROOLINE	LDENIIFIES I	AFE ERRORS
7 700000	TDCI	وارير بيات	
TPERK	LPSW	* + 4	DISABLE EXTERNAL DEVICE INTERRUPT
	DC	X 10000 1	
	DC	A (*+2)	
	NHI	4,X 0080	FIND OUT WHAT'S WRONG
	ΒZ	FPV	MUST BE FILE PROTECT VIOLATION
	BAL	15,0UPT	INDICATE TAPE FULL
	DC	A (TAPE1)	
	DC	H*24*	
	В	STOP	TERMINATE RUN
FPV	LHI	8. H 181	
	SSR	8.0	
	RTC	8.*-2	
	тит	9 7100201	REWIND COMMAND RYTE
	4700		UPATAD COULUMD DITT
	DAL	15,00PT	INDICATE FILE PROTECT VIOLATION
	DC	A (TAPEZ)	
	DC	H • 4 4 •	
	LPSW	*+4	HALT COMPUTER

	DC	X '80000080'
*		
TAPE1	DC	X * 8 D O A *
	DC	C'END OF TAPE REACHED '
TAPE2	DC	X * 8D0 A *
	DC	C'ATTEMPT TO WRITE ON FILE PROTECTED TAPE!
	DC	X '8D0 A '
* .		
NIL	DC	H *O *
RTEMPO	DS	Н
RTEMP1	DS	Н
RTEMP2	DS	Н
RTEMP3	DS	Н
RTEMP4	DS	Н
RTEMP5	DS	Н
RTEMP6	DS	Н
RTEMP7	DS	Н
PTR	DS	Н
CRUDE	DS	5 H
NFPTS	DS	Н
NMAX	DS	Н
MAX	DS	32H
SHMAX	DS	32C
IMAX	DS	32H
BHD	DS	10 H
BLO	DS	10H
BHU	DS	10 H
BOUT	DS	64F
BEND	EQU	*-2
*		

END