PRELIMINARY REPORT ON
RADIATION-INDUCED THERMOLUMINESCENCE
IN CLIMAX STOCK QUARTZ MONZONITE

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ABSTRACT

An examination has been made of the feasibility of using Thermoluminescence (TL) for the self-dosimetry of the rock surrounding a canister of nuclear waste. The rock investigated was quartz monzonite from the Climax Stock, a granite intrusive at the Nevada Test Site. Samples of the rock were irradiated by ^{60}Co to doses of 10^3 to 10^9 rads, then ground to a fine powder and read for TL response at a heating rate of 1°C per second. Effects of total dose, thermal history after irradiation, grinding to a powder after irradiation, mineral composition, and powder grain size were investigated. All were found to be important, but with care, the use of TL in this manner appears promising.

1.0 INTRODUCTION

Lawrence Livermore National Laboratory is conducting an experimental test of the emplacement of canisters of spent fuel from a commercial nuclear reactor in deep geologic storage^{1,2}. The experiment is being carried out at the Nevada Test Site, managed by the Nevada Operations Office of the Department of Energy, and is part of the Nevada Nuclear Waste Storage Investigations (NNWSI). One of the objectives of the Spent Fuel Test-Climax(SFT-C) is to determine what effects the radiation from the spent fuel will have on the rock in which the fuel is emplaced.

Little relevant experimental evidence is available concerning the effects of radiation on earth materials. Most radiation effects studies have been done at very high doses, or with neutron dosage only using engineering materials such as metals and ceramics. Quartz is the only natural mineral that has been studied in any detail. Therefore, preliminary studies are necessary in order to design an effective plan to document the radiation effects of the SFT-C, and to evaluate possible hazards associated with them⁽³⁾.

The purpose of this paper is to document a part of the radiation effects studies, specifically studies of radiation induced thermoluminescence of the rock from the SFT-C site. This phenomena is being investigated as a means of using the rock itself as a dosimeter. This paper is considered an interim report as much work remains to be done. Radiation effects studies have been deferred during FY81. This report serves as a summary of work to date. The level of effort has been quite low, with approximately three man-months

distributed within FY80, and another three man months in FY81 analyzing and reporting the data. At this level of funding, we have gathered together the existing literature, identified specific variables that may effect the TL of the minerals, developed an experimental plan to investigate some of those variables, and executed part of that plan.

2.0 THERMOLUMINESCENCE AND NATURAL MINERALS

Thermoluminescence (TL) is a phenomenon in which crystalline materials emit light when they are heated, after having been exposed to gamma radiation or charged particle bombardment. The TL of LiF crystals is used in personnel dosimetry at LLNL, and TL of quartz in pottery has been used in archeological dating. TL has been demonstrated (10), in quartz, potassium feldspar, plagioclase and pyrite, all prominent constituents of Climax Stock quartz monzonite (CSQM). Most natural mineral work has been with quartz, generally using hydrothermal quartz rather than the pyrogenic quartz of interest to us.

TL is measured by heating a sample at a constant rate in the presence of a light detector. The intensity of emitted light plotted as a function of temperature is called a glow curve (see Figure 1). A glow curve is composed of superimposed glow peaks that reach maxima at certain temperatures. The temperature distribution of glow peaks is characteristic of the material and the total radiation dose. The height and area of a glow peak generally increases with radiation dose until a saturation level is reached, characteristic of the particular glow peak. At higher doses the glow peak usually declines. Glow peaks decay with time depending on ambient temperature and the characteristics of the glow peak. Higher temperature glow peaks tend to be more stable (13).

TL originates from the energy released when trapped charges in the crystal return to their ground states. After a heating episode, all TL of a material below the highest temperature attained during heating is effectively cleared

and cannot be reread. The material will remain clear until it is exposed to radiation again. The energy released during TL is small with respect to the heat capacity of the crystals, so energy release due to heating is not expected to cause a runaway problem at repository temperatures.(8)

The mechanisms of TL are fairly well understood(4, 10, 13), and can be studied in detail if emission is recorded as a function of temperature and emission energy. It is outside of the scope of this paper to deal with the phenomena on an atomic scale. This study is designed to investigate macroscopic effects to experimentally determine the relationship between the TL of rock material and the absorbed radiation dose. The goal is to establish whether the TL of minerals from the Climax Stock quartz monzonite can be easily applied to dosimetry for the purpose of spent fuel test diagnostics.

Variables that may effect the measured thermoluminescence of mineral samples are: remnant TL, total dose, thermal history, mechanical treatment, composition of material, sample form, dose rate, and energy spectrum of the gamma radiation.

Variables specifically investigated in our preliminary experiments are remant TL, total dose, thermal history, mechanical treatment, composition of material, and sample form. These will be discussed in turn in the results section.

3.0 MATERIALS AND PROCEDURES

The source of rock material is NX core from the central portion of holes MB107, MB114 in the Climax Stock Quartz Monzonite (CSQM). The rock is medium to coarse grained porphyritic, with a ground mass composed of 40% plagioclase feldspar, 25% potassium feldspar, 28% quartz, 7% mafic minerals (biotite & magnetite) and accessory minerals. Phenocrysts of orthoclase 1-5 cm in size make up 5% of the rock, and quartz phenocrysts ~4mm in size make up 5-10% of

the rock. Samples were chosen to exclude large phenocrysts, obvious alteration zones and filled veins in an attempt to standardize the composition of whole rock samples. The rock core was prepared for irradiation in three ways, depending on the intended dose, and the means of irradiation. The samples were irradiated at one of two ^{60}Co sources at LLNL by Carl Huntzinger of Hazards Control. Irradiation was done under water, which causes some spread in the gamma spectrum.

Doses of 10^4 rads and greater were administered in C-cell of the standards and calibration laboratory. The C-cell dose rate is variable, depending on the position of the chip with respect to the ^{60}Co source, but is approximately 2000 (2420-1700) rads/sec at the center, the position reached by pneumatic transport. The samples irradiated at 10^4 to 10^5 rads were 1 cm diameter by 2-3 cm long cores cut from the NX core so they would fit in the pneumatic delivery system. On doses of 2×10^5 and greater exposure times were long enough that pneumatic delivery was not required, so these samples consisted of 1 cm disks sliced from the NX core with a diamond saw.

Doses below 10^4 rads were exposed at Site 300 with a dose rate of 736 rads/min ($\pm 3\%$). The samples again were disks of NX core, this time sliced to 1/2 cm or less since exposure in this facility is from one side only. All dose rates apply to absorbed dose in silicon, however we have assumed the same values for CSQM, since it has a similar average density and atomic number. Upon irradiation each sample was labeled with an ID number of the form ij-k where ij corresponds to the dose $i \times 10^j$, and k is a sequence number for multiple samples at the same dose.

Both whole rock and separate quartz samples have been tested for TL. Whole rock powder is prepared by crushing the rock disc in a jaw crusher. It is then pulverized in a Shatterbox Pulverizer for two minutes and sieved for

10 minutes with a mechanical shaker to obtain powders with various grain sizes. Prior to July 1980, rock powder samples were measured by volume, with an estimated mass size of .015-.025 gm. Whole rock samples read out in July 1980 and later, were weighed on a Sartorius analytical balance to 0.020 ± 0.001 grams.

Quartz samples have been prepared from the whole rock CSQM manually, using a stain to distinguish the quartz from the feldspar. The irradiated, crushed rock was sieved through #10 and #18 British standard (#12 and #20 U.A. standard) mesh to obtain a size fraction between 1680u and 841u. These grains were then stained as follows. First they were etched in 48% hydrofluoric acid for forty-five seconds, then they were rinsed thoroughly with water and washed twice with 5% barium chloride, then with sodium cobaltinitrite. Finally, they were rinsed with water again, washed twice with Rhodozonite, rinsed a final time and allowed to air dry at room temperature. After staining, the quartz was hand separated out as the light gray, unstained grains. The quartz was then pulverized and sieved in the same manner as the whole rock samples and 0.01 ± 0.0005 gram samples weighed out. Sample ID numbers for quartz separates have the prefix "Q" to distinguish them from whole rock samples, which either have no prefix or have the prefix "WR".

Irradiation of the rock was done in three sets. Two rock disks were irradiated in July 1979 to a dose of 10^9 rads, one as a disk and one as a powder (see Sect. 4.4). When significant thermoluminescence was detected in these samples, it was decided to begin a larger series of experiments to determine measureable dose range and the effects of important variables. A second set of irradiations in the ^{60}Co pool during Nov79-Mar80 included 32 rock samples irradiated as discs and six rock samples that were ground to a powder before irradiation (see Sect. 4.4). The dose range for the disk

irradiations included 16 doses $i \times 10^j$ where $i = 1, 2, 5$ $j = 4, 5, 6, 7, 8, 9$, with two rock discs irradiated at each dose (no irradiations at 2×10^9 or 5×10^9 were done in this batch). The powdered samples were irradiated to doses of 1×10^4 , 5×10^4 , 5×10^5 , 5×10^6 , 5×10^7 , and 5×10^8 rads. The third set of irradiations was done in July 1980 to extend the dose range, with 2 rock discs irradiated to a dose of 10^3 rads, and one disc each at 5×10^2 , 2×10^3 , 5×10^3 , 1×10^5 , and 2×10^9 rads.

These irradiated rock samples were prepared in various ways before being tested for TL response. The rock disk irradiated to 10^9 rads in July 1979 was ground and sieved to obtain the size fraction $< 44\mu$, and given sample label 19. The companion sample irradiated as a powder was sieved in the same way and labeled 19-p. These were the first samples tested for TL response and indicated there was sufficient response for further study.

As the samples from the Nov79-Mar80 irradiation batch became available, essentially one solid sample at each dose was ground to a powder as described earlier. On Jan 8, 1980 portions of the powder samples with doses of 1×10^5 through 2×10^6 were placed in a drying oven at 100°C .

The data in file APR80 represents the first attempt to investigate the effect of grain size on TL response. Prior to this period, grain size was not known to be an important variable, sieve size was not standardized, and detailed records were not kept on the size fractions used for the TL readings. The grain size values given in Appendix A for files Dec 79 through run number 157 in file Jul 80 are therefore "best estimates" and should not be considered rigorous.

During July, 1980, whole rock powder from irradiated rock samples in the dose range 10^3 rads to 2×10^8 rads and quartz separate powders irradiated to 1×10^7 through 2×10^8 rads were sieved to yield three particle size

fractions: coarse (100-150u), medium (50-100u), and fine (50u). These were identified by adding a 1, 2, or 3 respectively to the sample ID, changing its basic form to ij-k,n. The quartz samples were all read for TL in July 1980. The coarse whole rock samples were read during August 1980. The medium whole rock samples were read during November and December of 1980. The fine whole rock samples have not been weighed or read to date.

TL of the samples is read in a nitrogen atmosphere in the Harshaw Thermoluminescence Reader at LLNL Hazards Control. The planchet on which the sample is distributed is heated to 400°C at a rate of 1°C/sec by an electric current. This generates a glow curve which contains both TL and thermal (infra-red) emissions. Periodically the heating cycle is then repeated without disturbing the sample to obtain the thermal contribution. This second curve can be subtracted from the first to obtain a purely thermoluminescent glow curve. This was not done for the data presented here. The data for all runs made on the apparatus in a given month are accumulated in a computer data file identified by the month and year, e.g. Aug79. The glow curve values are stored at 1°C increments and are available for plotting or interval summing and printing as desired.

4.0 RESULTS

Appendix A is a summary of the readout runs made over the period July 79 to February 81 on the samples described in the previous section. The raw data for these runs are given in Appendix B. Selected data from Appendix B have been averaged in order to generate plots illustrating the various effects investigated. These averages and their associated standard deviations are given in Appendix C. Finally, Appendix D contains an inventory of the samples which remain after the work to date and which are available for future work,

e.g., investigation of TL decay with time, or x-ray analysis for mineral content.

4.1 REMANT TL

Remnant thermoluminescence in the minerals would be caused by their exposure to natural radiation in the Climax Stock. The amount of natural TL in the minerals from the CSQM can be expected to be relatively uniform, except where specific volumes of rock are adjacent to relatively strong sources of natural radiation. Tests on non-irradiated CSQM to date have indicated that remnant TL is below the detection limit of the configuration that we use, although remnant glow curves have been produced by others from CSQM mineral separates (10).

It has been shown (10) that the TL stored in a rock may be partially erased by exposure to light, and that exposure to light can generate TL. Since the samples used in the above tests were not specifically protected from light exposure, it is advisable to repeat those tests with such protection.

4.2 TOTAL DOSE

Total dose affects not only the intensity of TL, (defined as the area under the glow curve), but also the shape of the glow curve itself. This has been demonstrated in quartz by Fuller and Levy (5). Figure 2 shows the effect in CSQM whole rock samples. Nine glow curves from the Dec 80 data file, at doses from 5×10^5 to 2×10^8 , are superimposed. At the lower doses, most of the TL effect is at lower temperatures (80-200°C). As the dose increases, this lower peak saturates and then decreases, while another peak in the temperature range 220-390°C develops. (This higher temperature peak may be two or more peaks superimposed.) At still higher dose, this higher temperature peak also saturates and may decline.

Figure 3 shows the effect of total dose in another way, with integrated light intensity for selected segments of the glow curve plotted as a function of dose. Each point represents the mean of data from four rock powder samples. The data, from data files NOV80 and DEC80, are given in tabular form in Appendix C. The standard deviation of the TL intensity for the sample populations ranges from .4% - 16%. The selected segments are chosen to represent the two major peaks seen on Figure 2. The lines connecting the points are drawn to help the eye follow the data and have no other significance. Again we see the lower temperature peaks dominating at lower dose, the higher temperature peaks dominating at higher doses. There is a notable lack of sensitivity to dose in the dose range 10^3 to 10^4 rads. This is not likely to be an instrument sensitivity problem since other data (the heated samples read in early July 1980) have lower count rates. Possible causes are triboluminescence (TL generated in the grinding process), or temporal decay (the 10^3 samples were irradiated nearly 9 months later than the 10^4 samples). For the temperature range 110-220°C, the curves increase monotonically with dose from 10^4 to 2×10^6 rads, saturate in the range 2×10^6 to 10^7 rads, and decline smoothly above a dose of 10^7 rads. For the temperature range 220-390°C, the curve rises only moderately in the dose range 10^4 - 10^5 rads, become steeper (and more diagnostic) in the dose range 10^5 - 5×10^6 rads, and remains saturated over the dose range 5×10^6 - 2×10^8 rads. (Some experiments indicate that the curve declines somewhat at still higher doses.)

Total dose over a 5 year period to rock immediately adjacent to the spent fuel canisters is estimated to be 2×10^8 rads, with dose decreasing into the rock by approximately a factor of 10 every 12 cm (6). Thus, assuming that CSQM has a useful dosimetry range of 10^4 - 5×10^6 rads, the rock can document

its own dose in the annular region from 23 to 58 cm from the emplacement hole wall, using the integration regions of Figure 3. This diagnostic volume may be expanded by further calibration work in the low dose range, and by using integration regions at higher temperature. The equipment used to read out the TL effect can be extended to 600°C with minor modifications. Another approach(10) is to break the glow curves down into a set of theoretical sub-curves, each describing the TL response-vs-temperature for a particular energy trap, and use both the amplitudes and the center temperatures of those subcurves for diagnostic information.

4.3 THERMAL HISTORY

The thermal history of a sample after irradiation and before measurement of thermoluminescence is known to have a significant effect on the TL remaining to be measured. For a typical glow curve of TL versus temperature, exposure of a sample to a given temperature effectively erases the TL response below that temperature in a matter of seconds. Over geologic time normal earth temperatures may erase TL response to as high as 240°C. Figure 4 shows two glow curves for a dose of 10^6 rads; one taken after irradiation only, and one taken after an additional six months storage in an oven at about 100°C. As a result of this thermal treatment, the large peak at 140°C is missing from the glow curve for the heated sample, while the peak at 300°C appears to have increased somewhat in peak height and shifted to a higher temperature. The integrated intensity in the region 220-390°C is the same for the two curves within the standard deviation of the samples ($\pm 10\%$). For other doses tested, the integrated intensity of heated samples was lower than for non-heated samples by factors of 1.5-3, even in the higher temperature region of the glow curve. Heated rock powder data is in File JUL80 and are identified by the suffix "H" in the ID number.

This preliminary heating test was done in an oven not dedicated to this study and which varied in temperature somewhat while being used by others. Observations by the authors indicate the oven generally operated in the range 80-120°C, but one excursion to 140°C was noted. Little can be said from this test about annealing effects at points just above the exposure temperature, since the exposure temperature is not precisely known. However, those effects are likely to be important if any data is to be obtained from the lower temperature peak.

The rock in the SFT-C has already reached its maximum temperature of 80-90°C near the canisters (2). While annealing effects on the 300°C peak are expected to be minor, this should be confirmed by a more rigorously controlled experiment, and for accurate work, the precise amount of the effect should be measured as a function of temperature (30-90°C) and exposure time (1 month-5 years). A possible effect not investigated to date is the variation of TL response with temperature during irradiation. Other workers (11) have demonstrated both theoretically and experimentally a decrease in TL response as the irradiation temperature is reduced. These measurements need extension to the above room temperature environment of concern at the SFT-C.

4.4 Mechanical Treatment

The effect of mechanical treatment on the TL response of whole rock samples was examined by preparing several samples in the normal manner, but withholding irradiation until all grinding, sieving, etc., was completed. These samples were identified by the suffix "P" and shared a common grain size of 44u. Of the normal whole rock TL peaks at approximately 140°C, 280°C, and 320°C, the 140°C peak is substantially reduced by grinding after irradiation while the higher temperature peaks do not seem to be as affected, at least at doses of 10^9 rads (see Fig. 5). At the low dose of 10^4 rads

on the other hand, some reduction appears throughout the temperature range. This may be partly due to the fact that the higher temperature peaks are not well developed at low doses. The striking similarity of Figs. 4 and 5 suggests that the major effect of grinding may in fact be due to the heat generated in the grinding process. If this is so, it may be possible to control the effect by cooling the rock, and/or apparatus during grinding.

4.5 Material Composition

The composition and crystal structure of a material determine its TL response. The glow curve of a mixture of minerals, such as CSQM is the appropriately weighted sum of the glow curves of the constituent minerals. Although glow curves have been produced elsewhere for the quartz, k-feldspar plagioclase, and pyrite constituents of CSQM (10), the present work was limited to quartz and whole rock.

TL response in quartz is clearly different from that in whole rock. The quartz glow curve has a single peak at about 310°C (see Fig. 10), while whole rock exhibits peaks at 150°C and 300°C (Fig. 2).

4.6 Sample Form

The first quartz samples read in this work were done in early July to examine the effects of grain size and etching in hydrofluoric acid (to separate the quartz from other minerals). As shown in the table, etching increases the TL response about 10%, and although grain size has little effect in the high temperature interval of the glow curve, the medium samples read 40% higher in the 110-220°C interval.

<u>SAMPLE</u>	<u>ETCHED ?</u>	<u>GRAIN SIZE</u>	<u>110-220°C</u>	<u>220-390°C</u>
Q27-1MN	No	Medium	5.94×10^6	7.38×10^7
Q27-1FN	No	Fine	4.53×10^6	7.13×10^7
Q27-1ME	Yes	Medium	7.07×10^6	7.92×10^7
Q27-1FE	Yes	Fine	4.66×10^6	7.83×10^7

The first set of data taken to examine the grain size effect is from the APR80 file and is shown in Fig. 6. The curves corresponding to the 220-390°C temperature have the same shape for the two grain size fractions, but is about 70% higher for the medium powder, apparently independent of dose. The curves corresponding to the 110-220°C interval show a dose dependent effect, with the medium samples reading 114% higher at 10^5 rads, but only 29% higher at 2×10^8 rads.

Further evidence of the grain size effect can be had by comparing the 100-150u AUG80 data (Fig. 7) with the 50-100u NOV80 and DEC80 data (Fig. 3). Figure 8 shows the ratio of the TL values for the coarser AUG80 data to the finer NOV80 or DEC80 data. The circles indicate data for the 220-390°C interval of the curve while the squares indicate the 110-220°C interval. The effect on the two intervals appears to be identical at doses above 10^6 rads, but is 20-50% stronger for the lower interval at doses less than 10^6 rads.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Generally, readings at a given dose agree within a few percent, giving some confidence that TL can be used to measure dose in natural minerals, in particular CSQM. This confidence is somewhat shaken by a number of erratic and as yet unexplained results. Individual readings in Appendix B occasionally differ from their respective sets by 20-50%. The early July quartz readings differed from later readings at the same dose by an order of magnitude. Possible reasons are equipment malfunction, or operator error either in preparing the samples or in taking the readings themselves. Further work is needed in defining appropriate quality control procedures to reduce

this problem. In particular, background and TL standard samples should be employed rigorously in future work.

A major shift in instrument response appears to have occurred between the JUL80 and AUG80 data runs. This is evidenced by changes in background run values and in instrument characteristic parameters recorded in the operators log as well as in the TL data values. Otherwise, changes in observed TL for the same dose can be ascribed to specific sample differences such as grain size, heating episode, irradiated as a powder, etc.

The effect of grain size is evidenced in the literature by a decrease in TL with grain size. In the present work the reverse effect is seen, possibly because our data came from powders ground after irradiation. This can be checked by sieving some of the samples in Appendix D which were irradiated after grinding to examine the effect of grinding. Another possibility is that the grinding and sieving process causes a partial mineral separation. This could cause the different grain size fractions to have different mineral composition. The powder samples used can be analyzed with x-ray diffraction to answer this question.

The problem of sample composition is not limited to the grain size effect. Phenocrysts in the CSQM can be as large as 3-5 cm, i.e., the size of the disks which were irradiated. Thus the composition of 11 samples read should be checked by x-ray diffraction and if variation is found, it should be correlated with TL response. It has been shown that glow curves of quartz from different localities vary widely in response to identical radiation treatment (5). These differences are probably a function of trace element and defect content, and are assumed to be minor or insignificant in our experiments because only minerals from a small region of one lithologic unit, CSQM were used, and only rock that appeared unaltered was chosen. Fill material from

fractures should only be used with caution, as its date of deposition and origin, and thus trace element composition may be variable, In any case, large samples should be irradiated, and the subsequent powders well mixed before readout.

^{60}Co emits gamma radiation at 1.17 MeV and 1.33 MeV. The rock samples are irradiated in a pool of water, which causes some spread in the spectrum of the gamma radiation. The average energy of gamma radiation emitted by the spent fuel is 0.7 MeV. The spectrum of energies from the fuel is wide, ranging from 0.1 MeV to 3.5 MeV. The effects of different radiation sources, and of dose rate on thermoluminescence of quartz is unknown, and we have not planned any experiments to investigate these variables during this study. However, a variety of radiation sources are available at LLNL.

As a result of the work to date, it appears quite feasible to use the TL response of CSQM for self-dosimetry. A number of issues need clarification to make this feasibility a practical reality. In the SFT-C irradiation occurs during a heating episode. Therefore a thorough understanding of the fading of TL with time as a function of temperature, and the effect of temperature on the generation of TL during irradiation is crucial. A theory (10, 12, 13) exists to describe this behavior for a single glow peak in terms of the particular characteristics of that glow peak (glow peak "kinetics"). This implies a need to break the complex CSQM glow curves down into individual glow peaks for analysis. Software to do this has been developed (10), and should be implemented in this work.

Another critical issue is the effect of grinding, its effect on our grain size data, and whether it can be controlled by cooling the sample during grinding. The data reported here is from the upper and lower extremes of the

dose range, although samples exist (Appendix D) at intermediate doses, and should be read to document the effect uniformly as a function of dose.

Since TL response is affected by a number of environmental factors not obvious to the uninformed, a rigorous set of quality control procedures should be in place before the application of this newly developed technology to its intended use, the post-project self-dosimetry of the SFT-C rock.

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Fig.1-Whole roc L glow curve at 2×10^7 rads

Fig.2-TL response versus Temperature as a function of dose,rads

Fig.3-TL response as a function of dose, NOV80&DEC80 data, Grain size 50-100μ

Arbitrary Light Units

Fig.4-Effect of heating on TL response at 10^6 rads.

Fig.5-Effect of grinding on TL response at 10^9 rads.

Fig.6-Effect of grinding on TL response at 10^4 rads.

Fig.7-TL RESPONSE VERSUS DOSE AS A FUNTION OF GRAIN SIZE AND INTEGRATION INTERVAL

Fig.8-TL response as a function of dose,AUG80 data,Grain.size 100-150 μ

3-26-81 RCL

FIG 9, RELATIVE TL RESPONSE OF COARSE (100-150μ) TO MEDIUM (50-100μ) CSQM POWDER

Fig.19-Glow Curve for Quartz at 2×10^7 rads.

APPENDIX A, SUMMARY OF READOUT RUNS

File	Sample Ident*	Grain Size, u	#Runs	Run #'s	Dose Rads	Irrad. Batch
Aug 79	B		1	164		1
"	19	44	3	165, 167	1x10 ⁹	1
"	B		1	168		1
"	19-P	44	3	169-171	1x10 ⁹	1
Dec. 79	B	44	1	101		
"	14-1	44	2	100, 102	1x10 ⁴	2
"	19-P	44	2	103, 104	1x10 ⁹	1
"	14-2	44	2	105, 106	1x10 ⁴	2
"	24-1	44	2	107, 108	2x10 ⁴	2
"	24-2	44	2	109, 110	2x10 ⁴	2
"	54-1	44	2	111, 112, 112	5x10 ⁴	2
"	14-P	44		114, 115	1x10 ⁴	2
"	54-P	44	2	116, 117	5x10 ⁴	2
"	55-P	44	2	118, 119	5x10 ⁵	2
	B		1	120		
Feb. 80	14-1	44	2	102, 103	1x10 ⁴	2
"	24-1	44	2	104, 105	2x10 ⁴	2
"	15-1	44	2	106, 107	1x10 ⁵	2
"	16-1	44	3	108-110	1x10 ⁶	2
"	17-1	44	2	111, 112	1x10 ⁷	2
Apr 80	B		1	200		
"	25-1M	44-177	3	201-203	2x10 ⁵	2
"	25-1F	44	3	204-206	2x10 ⁵	2
"	26-1M	44-177	3	207-209	2x10 ⁶	2
"	26-1F	44	3	210-212	2x10 ⁶	2
"	27-1M	44-177	3	213-215	2x10 ⁷	2
"	27-1F	44	3	216-218	2x10 ⁷	2
"	28-2M	44-177	3	219-221	2x10 ⁸	2
"	28-2F	44	3	222-224	2x10 ⁸	2
Jul 80	B100		1	101		
"	Q27-1MN	88-150	3	100-103	2x10 ⁷	2
"	Q27-1FN	88	3	104-106	2x10 ⁷	2
"	Q27-1ME	88-150	3	107-109	2x10 ⁷	2
"	Q27-1FE	88	3	110-112	2x10 ⁷	2
"	WR15-1H	44	3	113-115	1x10 ⁵	2
"	B115		1	116		
"	WR25-1H	44	3	117-119	2x10 ⁵	2
"	WR55-1H	44	3	120-122	5x10 ⁵	2
"	WR16-1H	44	3	123-125	1x10 ⁶	2
"	WR26-1H	44	3	126-128	2x10 ⁶	2
"	WR13-1	?	3	129, 131-132	1x10 ³	3
"	B129		1	130		
"	WR13-1	?	1	133	1x10 ³	3
"	B133		1	134		

<u>File</u>	<u>Sample Ident*</u>	<u>Grain Size</u>	<u>#Runs</u>	<u>Run #'s</u>	<u>Dose Rads</u>	<u>Irrad. Batch</u>
Jul 80	B146		1	147		
"	WR-25-1HR	44	3	146, 148, 149	2x10 ⁵	2
"	26-1MR	44-177	3	150-152	2x10 ⁶	2
"	B152			153		
"	16-1FR	44	3	154, 156, 157		2
"	B154		1	155		
"	Q18-2,1	100-150	1	158	1x10 ⁸	2
"	Q18-2,2	50-100	3	159, 161, 162	1x10 ⁸	2
"	B159		1	160		
"	Q18-2,3	50	3	163, 165, 166	1x10 ⁸	2
"	B163		1	164		
"	Q28-2,1	100-150	3	167, 169, 170	2x10 ⁸	2
"	Q28-2,2	50-100	3	171-173	2x10 ⁸	2
"	Q28-2,3	50	3	174-176	2x10 ⁸	2
"	Q27-1,1	100-150	3	177-179	2x10 ⁷	2
"	Q27-1,2	50-100	3	180-182	2x10 ⁷	2
"	Q27-1,3	50	3	183-185	2x10 ⁷	2
"	Q17-1,2	50-100	3	186-188	1x10 ⁷	2
"	Q17-1,3	50	3	189-191	1x10 ⁷	2
"	Q57-1,1	100-150	1	192	5x10 ⁷	2
"	Q57-1,2	50-100	3	193-195	5x10 ⁷	2
"	Q57-1,3	50	3	196-198	5x10 ⁷	2
Aug 80	WR13-1,1	100-150	4	100, 102, 104	1x10 ³	3
"	B100		1	101		
"	WR14-1,1	100-150	4	105-108	1x10 ⁴	2
"	WR24-1,1	100-150	4	109-112	2x10 ⁴	2
"	WR54-1,1	100-150	4	113-116	5x10 ⁴	2
"	WR15-1,1	100-150	4	117-120	1x10 ⁵	2
"	WR25-1,1	100-150	4	121-124	2x10 ⁵	2
"	WR55-1,1	100-150	4	125-128	5x10 ⁵	2
"	WR16-1,1	100-150	4	129-132	1x10 ⁶	2
"	WR26-1,1	100-150	4	133-136	2x10 ⁶	2
"	WR56-1,1	100-150	4	137-140	5x10 ⁶	2
"	WR17-1,1	100-150	3	141-143	1x10 ⁷	2
"	WR17-1,1	100-150	1	144	1x10 ⁷	2
"	WR27-1,1	100-150	4	145-148	2x10 ⁷	2
"	WR57-1,1	100-150	4	149-152	5x10 ⁷	2
"	WR18-1,1	100-150	4	153-156	1x10 ⁸	2
"	WR28-1,1	100-150	4	157-160	2x10 ⁸	2
Nov 80	B		1	210		
"	WR13-1,2	50-100	4	211-214	1x10 ³	3
"	WR14-1,2	50-100	4	215-218	1x10 ⁴	2
"	24-1,2	50-100	5	219-223	2x10 ⁴	2
"	54-1,2	50-100	4	224-227	5x10 ⁴	2
"	15-1,2	50-100	4	228-231	1x10 ⁵	2
"	25-1,2	50-100	4	232-235	2x10 ⁵	2

<u>File</u>	<u>Sample Ident*</u>	<u>Grain Size</u>	<u>#Runs</u>	<u>Run #'s</u>	<u>Dose Rads</u>	<u>Irrad. Batch</u>
Dec 80	55-1,2	50-100	4	101-104	5×10^5	2
"	16-1,2	50-100	4	105-108	1×10^6	2
"	26-1,2	50-100	4	109-112	2×10^6	2
"	56-1,2	50-100	4	113-116	5×10^6	2
"	17-1,2	50-100	4	117-120	1×10^7	2
"			2	121,122		
"	27-1,2	50-100	4	123-126	2×10^7	2
"	57-1,2	50-100	3	127-129	5×10^7	2
"	18-2,2	50-100	4	130-133	1×10^8	2
"			2	134,135		
"	28-2,2	50-100	4	136-139	2×10^8	2
Feb 81**	19	44	3	100-102	1×10^9	1
"	19P	44	3	103-105	1×10^9	1

*

B = Background

H = Heated after Irrad.

Q = Quartz separate

P = Irrad. as powder

N = Not etched

E = Etched

R = Rerun

** planchet sample not weighed

Irradiation Batch

1 = July 79

2 = Nov79-Mar80

3 = July 80

o-MAR-81

REGIONS

1	START: 110 STOP: 170 BKG. COUNTS:	0
2	START: 220 STOP: 390 BKG. COUNTS:	0
3	START: 170 STOP: 220 BKG. COUNTS:	0
4	START: 190 STOP: 250 BKG. COUNTS:	0
5	START: 270 STOP: 350 BKG. COUNTS:	0
6	START: 140 STOP: 200 BKG. COUNTS:	0
7	START: 240 STOP: 380 BKG. COUNTS:	0

AUG-79

SAMPLE ID	RUN	REGION						
		1	2	3	4	5	6	7
19	155	988	6925	489	695	4193	931	6367
	165	1123	7525	546	862	4670	1024	6944
	167	1341	8683	776	1231	5378	1354	7951
	168	0	0	0	0	0	0	0
19-P	169	7136	7136	2257	2099	4188	5002	6349
	170	8071	8451	2704	2521	4943	6089	7506
	171	6495	6833	2142	1955	4009	4785	6084

7425

27-FEB-81

REGIONS

1 START: 110 STOP: 170 BKG. COUNTS: 0
 2 START: 220 STOP: 390 BKG. COUNTS: 0
 3 START: 170 STOP: 220 BKG. COUNTS: 0
 4 START: 190 STOP: 250 BKG. COUNTS: 0
 5 START: 270 STOP: 350 BKG. COUNTS: 0
 6 START: 140 STOP: 200 BKG. COUNTS: 0
 7 START: 240 STOP: 300 BKG. COUNTS: 0

Sample
ID

	NUM	DEC79 REGION	REGION	REGION	REGION	REGION	REGION	REGION
		1	2	3	4	5	6	7
14-1	100	38290	45354	28199	28604	18408	35024	34473
	102	40640	45019	28444	29499	17830	37463	33685
19-P	103	417837	977427	236469	257787	550449	400115	859799
	104	450520	1011477	272924	282119	577947	481093	891576
14-2	105	34459	54220	24790	25811	24486	33309	43261
	106	34981	46254	26088	27047	18819	33755	35362
24-1	107	104297	57433	53439	46561	21944	90396	41756
	108	134047	66041	59290	49263	25273	98183	49305
24-2	109	95374	57334	46586	39874	22477	77819	43043
	110	86261	53813	42292	36788	21122	68025	40400
54-1	111	340144	88571	125743	87970	32241	257622	63780
	112	220415	69113	96038	69933	24550	188221	48337
	113	351170	87960	117837	82821	32432	246865	64011
14-P	114	152404	119516	95688	87970	47419	134999	89973
	115	142500	111795	89744	83194	44015	132570	83594
54-P	116	886715	156950	251308	171193	56062	544510	111101
	117	911404	150206	270990	177352	52070	606091	104947
55-P	118	4420677	396559	1022397	533945	143690	2895007	279229
	119	4640087	420309	1058507	566883	151374	3019447	297581

STOP AT LINE 930

READY

27-FEB-81

REGIONS

1	START: 110 STOP: 170 BKG. COUNTS:	0
2	START: 220 STOP: 390 BKG. COUNTS:	0
3	START: 170 STOP: 220 BKG. COUNTS:	0
4	START: 190 STOP: 250 BKG. COUNTS:	0
5	START: 270 STOP: 350 BKG. COUNTS:	0
6	START: 140 STOP: 200 BKG. COUNTS:	0
7	START: 240 STOP: 380 BKG. COUNTS:	0

FEB80

RUN	REGION	REGION	REGION	REGION	REGION	REGION	REGION
*	1	2	3	4	5	6	7
100	0	1936	0	0	108	0	1107
101	145850	103590?	184612	254684	499611	186744	869715
14-1 102	46922	65012	42409	43995	25565	54402	48611
103	45019	66340	40598	42343	26508	53158	50170
24-1 104	99923	63036	63948	52215	23326	111437	46154
105	113278	64729	60420	51109	24635	96291	47857
106	386945	90286	151991	100330	33751	315759	64452
15-1 107	411812	90521	196421	95337	35008	315725	65947
108	411488?	12405??	112354?	799888	619708	298721?	100779?
16-1 109	479687?	133041?	231009?	114944?	622797	537246?	105149?
110	3610/??	120803?	184153?	961271	594430	398612?	972578
17-1 111	534590?	130560??	235765?	277938?	876054?	470956?	119475??
112	591674?	173203??	262852?	271661?	121244??	486857?	160154??

REGIONS

1 START: 110 STOP: 170 BKG. COUNTS: 0
 2 START: 220 STOP: 390 BKG. COUNTS: 0
 3 START: 170 STOP: 220 BKG. COUNTS: 0
 4 START: 190 STOP: 250 BKG. COUNTS: 0
 5 START: 270 STOP: 350 BKG. COUNTS: 0
 6 START: 140 STOP: 200 BKG. COUNTS: 0
 7 START: 240 STOP: 380 BKG. COUNTS: 0

SAMPLE ID	RUN	APK80						
		REGION	REGION	REGION	REGION	REGION	REGION	REGION
		1	2	3	4	5	6	7
25-1M	201	139379?	203099	474873	263399	72584	118773?	142162
	202	207321?	288631	836028	442299	96457	212073?	193092
	203	154065?	279443	479938	298946	106445	106619?	205237
25-1F	204	959060	167433	281640	173820	63467	645279	122340
	205	713427	137519	246496	157066	51100	516040	98641
	206	650142	128342	236011	150248	47991	483075	92176
26-1M	207	621256?	505891?	220119?	212157?	288410?	497033?	433260?
	208	438695?	465140?	320684?	224358?	260526?	595833?	396728?
	209	511724?	531368?	203100?	204307?	306186?	437894?	459539?
26-1F	210	328466?	298929?	135258?	124939?	168492?	292014?	257117?
	211	353023?	304795?	142508?	128798?	171290?	314801?	262058?
	212	296994?	284952?	131726?	118271?	161992?	267844?	245438?
27-1M	213	236267?	108931?	121047?	178632?	746108?	182704?	100545??
	214	206370?	138991??	130553?	202228?	963375?	210806?	128958??
	215	224922?	116008??	132530?	196946?	797595?	220864?	107156??
27-1F	216	157474?	689338?	104265?	136873?	452542?	175955?	630540?
	217	173200?	658880?	886578	127823?	432274?	140782?	602088?
	218	170016?	652889?	103634?	133273?	429609?	176755?	596714?
28-2M	219	169298?	117047??	905519	174751?	797049?	124246?	108216??
	220	107244?	124313??	756689	162705?	841503?	885334	115090??
	221	133402?	110615??	823597	144833?	748383?	126312?	102780??
28-2F	222	100978?	834443?	641839	125973?	554016?	829080	769196?
	223	105946?	756335?	658425	112677?	489781?	877330	694854?
	224	992659	701216?	634002	112972?	455377?	822638	642136?

1 START: 110 STOP: 170 BKG. COUNTS: 0
 2 START: 220 STOP: 390 BKG. COUNTS: 0
 3 START: 170 STOP: 220 BKG. COUNTS: 0
 4 START: 190 STOP: 250 BKG. COUNTS: 0
 5 START: 270 STOP: 350 BKG. COUNTS: 0
 6 START: 140 STOP: 200 BKG. COUNTS: 0
 7 START: 240 STOP: 380 BKG. COUNTS: 0

JUL80							
RUN	REGION	REGION	REGION	REGION	REGION	REGION	REGION
0	1	2	3	4	5	6	7
100	1266237	787045??	4266497	12202677	42093277	2674397	70785677
Q27-1M	101	0	1971697	136	1986	448353	0
	102	1215967	66285977	4235537	11970677	37006777	2591817
	103	1547697	76424977	5280557	14901577	39828277	3266647
	104	1156967	73265677	3508757	9484577	51848377	2306317
Q27-1FN	105	1076957	70505977	3412407	9250227	49778677	2235537
	106	1057007	70086077	3370867	9104237	49551277	2219847
	107	1545927	76529877	5295687	14703277	39661077	3342177
Q27-1ME	108	1570497	79378077	5405687	15009077	41331277	3428447
	109	1588147	81564477	5807127	16117177	41729677	3645157
	110	1062077	74717677	3417227	9150377	53099877	2247847
Q27-1FE	111	1166077	84513877	3833787	10284477	60079177	2510567
	112	1070587	75573377	3425647	9165317	53590377	2263337
	113	37	62313	1061	4753	39137	363
WR15-1H	114	0	38029	200	2108	22703	0
	115	0	45156	259	2580	26863	4
B	116	0	4457	0	0	498	0
	117	0	73450	147	817	36756	37
WR25-1H	118	0	83562	132	923	42009	33
	119	0	78621	95	807	40519	18
	120	13	289435	1817	11774	189834	529
WR55-1H	121	138	322224	2614	15299	227454	973
	122	85	290802	2132	12186	193680	802
	123	348	1278137	14054	93098	936623	3600
WR16-1H	124	188	1023577	11863	81005	737019	2702
	125	134	1126607	12371	92130	825672	2420
	126	0	3093927	3522	35798	2566187	579
WR26-1H	127	0	3044037	3908	36982	2525677	695
	128	0	4600977	4194	42526	3704077	754
	129	21413	73883	30194	36060	33836	30885
	130	0	6237	0	0	1382	0
NR13-1	131	19078	69299	29953	35779	30529	30780
	132	18475	65635	28917	34160	28456	29708
	133	20431	67590	29362	35115	29233	30207
	134	0	5939	0	0	1305	0
	146	0	13065	0	0	1896	0
WR-25-1HR	148	191	78869	923	1927	41637	635
	149	2149	104402	3031	4338	54224	3497
	150	5327967	8856687	4072757	3263597	5427597	7047967
26-1MR	151	5323297	9267417	4369017	3465297	5657077	7440957
	152	5443327	8787817	4211847	3328747	5255697	7345517
	153	0	51162	0	22	11073	0
	154	4802357	6701847	3590737	2816117	3235427	6359847
26-1FR	155	0	53558	0	41	10637	0
	156	4924627	6567567	3310287	2697797	3907547	5861927
	157	4037987	6405307	3766677	2752787	3829537	6010727
Q18-2,1	158	66502	12630377	235380	886375	8962507	136764
	159	78066	14502977	285449	1109657	10417777	157952
	160	0	271827	21	399	41453	0
Q18-2,2	161	71485	13546777	268878	1047597	9777097	149649
	162	81574	15818877	300215	1158597	11282877	170294
	163	99493	18589277	369352	1437157	13439077	204264
Q18-2,3	164	0	324410	12	382	71922	0
	165	94578	18155777	353649	1362577	13045877	197857
	166	89292	18027677	342465	1328197	12980177	191967
	167	102284	11375177	312790	1018067	7801507	203315
	168	0	227207	0	161	47919	0
Q28-2,1	169	117411	12174877	340069	1146017	8360807	212667
	170	99890	11542177	306545	1028867	7981197	197185
	171	111281	12139177	336622	1121147	8429367	214649
Q28-2,2	172	115744	12241977	347143	1152487	8488567	221046
	173	127301	13175777	381744	1275637	9161607	240934
	174	125968	13319077	380870	1271887	9255537	241110
Q28-2,3	175	125317	13315977	383077	1282677	9271287	242048
	176	120141	12585077	361393	1208127	8725277	229043
	177	96666	5429057	271614	702261	3740097	192740
Q27-1,1	178	93979	5371587	266243	686240	3687267	189542
	179	87933	5434277	266827	688736	3741287	188783
	180	86098	5153017	232337	595892	3481927	166485
Q27-1,2	181	78321	4685017	218254	557692	3186147	155617
	182	84646	5048747	242681	627325	3476427	171407
	183	108993	6295977	311782	809582	4346127	219103
Q27-1,3	184	95104	6077167	288268	746009	4188697	204400
	185	95914	5935797	287731	745213	4093527	203639
	186	241373	14479377	930585	2190937	9973997	617473
Q17-1,2	187	240542	15396977	980335	2313947	10612377	642555
	188	253010	16060177	1028157	2421287	11043677	675203
	189	310598	18880577	1241677	2924437	13013977	814352
Q17-1,3	190	282196	17375877	1131487	2660747	11978777	743025
	191	245806	14942277	907893	2164947	10308077	598528
Q57-1,1	192	639192	56000877	1636677	5331477	40962477	1142807
	193	588351	49020977	1564527	5088817	35481477	1050337
Q57-1,2	194	644592	54577577	1734117	5653337	39493577	1173197
	195	591028	49040177	1582367	5124197	35434877	1081177
	196	363707	27728777	890734	2729757	19875177	657119
Q57-1,3	197	340095	26365677	857072	2626877	18813277	621610
	198	392289	29443077	1098777	3114537	21178877	714210

REGIONS
 1 START: 110 STOP: 170 BKG. COUNTS: 0
 2 START: 220 STOP: 390 BKG. COUNTS: 0
 3 START: 170 STOP: 220 BKG. COUNTS: 0
 4 START: 190 STOP: 250 BKG. COUNTS: 0
 5 START: 270 STOP: 350 BKG. COUNTS: 0
 6 START: 140 STOP: 200 BKG. COUNTS: 0
 7 START: 240 STOP: 380 BKG. COUNTS: 0

AUGUST							
RUN	REGION	REGION	REGION	REGION	REGION	REGION	REGION
#	1	2	3	4	5	6	7
100	19365	85503	30217	38836	39901	29505	68339
101	0	8881	0	0	1780	0	5001
WR13-1,1	102	20077	86774	33167	41809	39422	68569
	103	20347	86883	33717	42410	39249	68489
	104	17168	75196	28898	36551	33747	59165
	105	25915	86734	32135	36643	28583	51504
WR14-1,1	106	23947	89823	31530	35821	32122	55165
	107	24457	81567	31830	36467	40316	66125
	108	24424	59737	31072	34386	25381	46010
	109	104963	110695	94027	85603	43966	137326
WR24-1,1	110	107153	115757	100177	90188	45881	85319
	111	104262	108905	95346	85533	42956	80258
	112	108626	117588	98152	88731	47330	87534
	113	256535	155760	200349	151074	59684	111788
WR54-1,1	114	290217	173362	205573	156887	70000	127770
	115	255702	152732	197305	149812	58037	109396
	116	287817	164168	210363	159097	62948	118388
	117	378031	158378	258849	173557	61266	113072
WR15-1,1	118	373592	160898	261913	177128	62149	114750
	119	378289	159160	258796	174457	61698	113710
	120	359362	159341	258654	175102	61687	113535
	121	987628	306784	403369	341281	113665	220495
WR25-1,1	122	1043727	308473	561777	341947	115620	234116
	123	966745	307678	566119	346734	116950	223362
	124	994140	286263	552962	333508	105996	206073
	125	6095957	1289697	2638207	1352487	533770	960070
WR55-1,1	126	5676597	1449467	3718517	1696387	588115	1062097
	127	4353827	984338	2501357	1131557	402914	721105
	128	5586547	1254557	2782487	1345667	515416	929922
	129	3843887	2143817	2491817	1420647	1121807	1765197
WR6-1,1	130	3575867	1941007	2266877	1293207	1009157	1595267
	131	3955957	2088747	2070937	1322987	1095357	1724487
	132	3741887	2030517	2281747	1321277	1056237	1672127
	133	10862377	18151577	8614547	6912777	10847477	15184577
WR26-1,1	134	11493377	16749977	6869967	6267657	9957677	14621077
	135	10370377	17275477	8430887	6698217	10295177	15093677
	136	9771707	16652077	7741757	6216747	10039177	14610277
	137	7524807	22758477	5945627	5926967	14854377	20548977
WR56-1,1	138	7364077	25556377	6599687	6534467	16724577	23105477
	139	8089087	24729477	6122997	6365577	16123677	22327777
	140	7636797	24941977	5984657	6210137	16431077	22596677
	141	2223377	17250677	2258287	3013387	12036177	3191037
WR17-1,1	142	2244637	16580577	2207847	2951677	11532577	3199797
	143	2275537	16435177	2165677	2871847	11439777	3204047
	144	2272227	16740877	2044707	2872497	11648877	2984487
	145	2866767	21959077	2211927	3458067	15471277	3228097
WR27-1,1	146	2896827	24630477	2414387	3774417	17388477	3461487
	147	2897847	24319677	2342567	3782077	17146777	3338427
	148	2716597	23480877	2487257	3743447	16517077	3550597
	149	1827287	22790477	1691907	2947677	16209277	2296247
WR57-1,1	150	1949367	23471577	1706177	2997697	16771277	2438627
	151	2072627	26485277	1998537	3463167	18940477	2789257
	152	1823037	22996777	1746667	2939167	16414677	2454187
	153	1296767	14284577	1229627	1870937	10065177	1791987
WR18-1,1	154	1232877	12961177	1130577	1720107	9124567	1667847
	155	1380447	13753077	1138507	1819807	9640887	1689657
	156	1234567	13283177	1066357	1712587	9278747	1544717
	157	1584567	23451577	1647317	2846397	16486877	2233167
WR28-1,1	158	1421407	23760877	1589497	2793987	16704277	2069567
	159	1699767	24074877	1459557	2849227	16991277	1901667
	160	1566107	25374277	1619597	2905667	18017677	2151407

REGIONS

1	START: 110 STOP: 170 BKG. COUNTS:	0
2	START: 220 STOP: 390 BKG. COUNTS:	0
3	START: 170 STOP: 220 BKG. COUNTS:	0
4	START: 190 STOP: 250 BKG. COUNTS:	0
5	START: 270 STOP: 350 BKG. COUNTS:	0
6	START: 140 STOP: 200 BKG. COUNTS:	0
7	START: 240 STOP: 380 BKG. COUNTS:	0

		NOV80						
	RUN	REGION	REGION	REGION	REGION	REGION	REGION	REGION
	#	1	2	3	4	5	6	7
WR13-1,2	211	13728	86071	25495	34178	42048	23915	70135
	212	15217	93602	26122	35314	46770	24337	76981
	213	13173	76294	21676	29511	36694	20773	62146
	214	12487	78417	21193	29264	38000	20016	64083
WR14-1,2	215	24210	69037	30946	36884	30339	34486	53553
	216	27998	79516	35180	41883	35312	39306	62009
	217	29813	73096	36284	41294	31615	41509	56384
	218	27445	75489	35483	41178	32746	39566	58436
24-1,2	219	71925	91122	67071	64952	36972	91983	67844
	220	71189	98374	68339	67062	40745	92188	73997
	221	79401	95625	73870	71576	38438	100811	70550
	222	67796	90855	66417	64938	36586	89666	67500
54-1,2	223	72914	100202	73270	71139	40295	100055	74378
	224	160376	117104	124279	104559	45365	192137	84179
	225	153372	114669	130198	107393	42919	201634	81265
	226	196844	128284	145624	119910	48891	231238	91357
15-1,2	227	156660	116703	120567	100792	45412	188091	84378
	228	220552	130604	181664	138245	48877	281833	91134
	229	219007	124028	175720	132267	46667	276561	86581
	230	237283	134519	190871	144011	50526	300113	93675
25-1,2	231	185971	117802	158971	121786	43998	242490	82488
	232	419731	197617	343114	238427	69554	551257	134401
	233	425249	188009	322742	232810	63939	516861	124619
	234	453454	182578	318282	219233	65135	528140	125292
	235	387642	177181	301359	216856	60670	475644	118383

REGIONS

1	START: 110 STOP: 170 BKG. COUNTS:	0
2	START: 220 STOP: 390 BKG. COUNTS:	0
3	START: 170 STOP: 220 BKG. COUNTS:	0
4	START: 190 STOP: 250 BKG. COUNTS:	0
5	START: 270 STOP: 350 BKG. COUNTS:	0
6	START: 140 STOP: 200 BKG. COUNTS:	0
7	START: 240 STOP: 380 BKG. COUNTS:	0

		DECHU						
		RUN	REGION	REGION	REGION	REGION	REGION	REGION
		1	2	3	4	5	6	7
<hr/>								
55-1,2								
55-1,2	101	1185597	472219	1030847	577685	192909	1718687	335469
	102	1297437	415953	868009	495724	170027	1581637	297641
	103	1447027	465018	983471	556395	188450	1815007	330671
	104	1466087	470940	953007	558175	188912	1763127	335551
<hr/>								
16-1,2								
16-1,2	105	1518777	1186217	1304427	808342	636084	2112197	975046
	106	1431607	1210927	1525487	931584	632637	2325097	978240
	107	1560527	1188687	1485427	879589	625736	2397337	965650
	108	1400317	1098137	1234197	775540	583206	1965727	896721
<hr/>								
26-1,2								
26-1,2	109	2060887	3757117	1959077	1511467	2255417	2966367	3292877
	110	2646787	4134647	2227867	1705247	2465847	3617627	3610357
	111	2234527	3674277	2043877	1531227	2205097	3158997	3216247
	112	2146757	3637427	1911887	1466997	2180187	2989207	3185397
<hr/>								
56-1,2								
56-1,2	113	1924317	7609987	2008517	1949507	4870577	2851227	6880477
	114	2970577	9465187	2563127	2471327	6083737	3994967	8540827
	115	1801327	7731627	1928837	2011197	4934617	2674597	6972137
	116	1909867	7296337	1945357	1958987	4669377	2824907	6570417
<hr/>								
17-1,2								
17-1,2	117	1212677	9321257	1151187	1647307	6269497	1545697	8580117
	118	1245197	9257497	1164607	1605777	6180077	1596467	8516097
	119	1048117	9003887	1137757	1526807	5984837	1511527	8283827
	120	715738	8065437	925919	1377497	5475597	1103317	7441637
<hr/>								
27-1,2								
27-1,2	121	0	1342	0	0	35	0	722
	122	0	1275	0	0	11	0	660
	123	1065047	7950757	916858	1284567	5377157	1262427	7352497
	124	969161	7591537	888026	1248317	5137367	1187517	7015447
<hr/>								
57-1,2								
57-1,2	125	947466	7739727	872637	1248917	5278237	1158147	7165267
	126	720782	7525237	754730	1179207	5162407	923583	6975727
	127	654132	7857537	653588	1032017	5282587	825044	7304127
	128	834934	9365357	810794	1286407	6440897	1030667	8725037
<hr/>								
18-2,2								
18-2,2	129	494479	905099	651566	1218777	0	696276	460449
	130	623783	7951717	605427	938790	5299517	789204	7401527
	131	481968	6136397	499788	745392	3964877	648589	5659027
	132	749564	9024507	683939	1109727	6106457	902849	8410577
<hr/>								
28-2,2								
28-2,2	133	532828	8053827	559294	961418	5402267	678558	7504007
	134	0	747	0	0	0	0	266
	135	0	1197	0	0	179	0	716
	136	397503	7839347	488915	868758	5214057	560271	7310097
<hr/>								
28-2,2								
28-2,2	137	492833	8098917	535972	920098	5362867	652457	7542767
	138	521272	7381097	519183	016803	4746607	670688	6846637
	139	558305	9445927	619175	1131067	6382667	736976	8810187

End Readout

REGIONS

1	START: 110 STOP: 170 BKG. COUNTS:	0
2	START: 220 STOP: 390 BKG. COUNTS:	0
3	START: 170 STOP: 220 BKG. COUNTS:	0
4	START: 190 STOP: 250 BKG. COUNTS:	0
5	START: 270 STOP: 350 BKG. COUNTS:	0
6	START: 140 STOP: 200 BKG. COUNTS:	0
7	START: 240 STOP: 380 BKG. COUNTS:	0

FEB88

RUN	REGION	REGION	REGION	REGION	REGION	REGION	REGION
4	1	2	3	4	5	6	7
19	100	137037	166075?	153081	238359	102260?	191658
	101	88877	152176?	155686	202841	906932	175431
	102	84572	113372?	105687	147769	680768	130495
	103	336417	131383?	303543	316923	762722	451036
19-P	104	322732	121588?	290189	300207	692650	424739
	105	288251	146805?	402414	384055	845865	525920
							1296472

APPENDIX C - Data for Figures

<u>File</u>	<u>Sample</u>	<u># Readings</u>	<u>110-220oC</u>	<u>220-390oC</u>
*Aug 79	19	3	4.27x10 ⁵ (+11%)	1.88x10 ⁶ (+7%)
	19-P	3	2.34x10 ⁶ (+6%)	1.82x10 ⁶ (+7%)
Dec 79	14-1, 14-2	4	6.40x10 ⁴ (+4%)	4.77x10 ⁴ (+5%)
	24-1, 24-2	4	1.55x10 ⁵ (+9%)	5.87x10 ⁴ (+4%)
	54-1	2	4.67x10 ⁵ (+4%)	8.83x10 ⁴ (+3%)
	14-P	2	2.40x10 ⁵ (+3%)	4.52x10 ⁴ (+4%)
	54-P	2	1.16x10 ⁶ (+2%)	1.54x10 ⁵ (+2%)
	55-P	2	5.57x10 ⁶ (+2%)	4.08x10 ⁵ (+3%)
	19-P	2	6.89x10 ⁵ (+5%)	9.94x10 ⁵ (+2%)
Feb 80	14-1	2	8.75x10 ⁴ (+2%)	6.57x10 ⁴ (+1%)
	24-1	2	1.69x10 ⁵ (+3%)	6.39x10 ⁴ (+1%)
	15-1	2	5.49x10 ⁵ (+2%)	9.04x10 ⁴ (+1%)
	16-1	3	5.93x10 ⁶ (+10%)	1.26x10 ⁶ (+3%)
	17-1	2	7.12x10 ⁶ (+8%)	1.51x10 ⁷ (+14%)
Apr 80	25-1F	3	1.07x10 ⁶ (+10%)	1.44x10 ⁵ (+8%)
	26-1F	3	4.69x10 ⁶ (+4%)	2.96x10 ⁶ (+2%)
	27-1F	3	2.67x10 ⁶ (+1%)	6.67x10 ⁶ (+2%)
	28-2F	3	1.72x10 ⁶ (+2%)	7.64x10 ⁶ (+5%)
	25-1H	3	2.29x10 ⁶ (+13%)	2.57x10 ⁵ (+10%)
	26-1M	3	7.79x10 ⁶ (+6%)	5.01x10 ⁶ (+4%)
	27-1M	3	3.55x10 ⁶ (+3%)	1.21x10 ⁷ (+10%)
	28-2M	3	2.22x10 ⁶ (+11%)	1.17x10 ⁷ (+11%)
Jul 80	WR15-1H	3	5.19x10 ² (+56%)	4.85x10 ⁴ (+15%)
	WR25-1H	3	1.25x10 ² (+12%)	7.85x10 ⁴ (+4%)
	WR25-1HR	3	2.10x10 ³ (+75%)	6.54x10 ⁴ (+42%)
	WR55-1H	3	2.27x10 ³ (+12%)	3.00x10 ⁵ (+4%)
	WR16-1H	3	1.30x10 ⁴ (+6%)	1.14x10 ⁶ (+6%)
	WR26-1H	3	3.87x10 ³ (+5%)	3.58x10 ⁶ (+14%)
	WR13-1	4	4.95x10 ⁴ (+2%)	6.91x10 ⁴ (+3%)
	26-1MR	3	9.58x10 ⁶ (+1%)	8.97x10 ⁶ (+2%)
	26-1FR	3	8.14x10 ⁶ (+2%)	6.56x10 ⁶ (+1%)
	Q27-1MN	3	5.94x10 ⁶ (+8%)	7.38x10 ⁷ (+5%)
	Q27-1FN	3	4.53x10 ⁶ (+2%)	7.13x10 ⁷ (+1%)
	Q27-1ME	3	7.07x10 ⁶ (+2%)	7.92x10 ⁷ (+2%)
	Q27-1FE	3	4.66x10 ⁶ (+4%)	7.83x10 ⁷ (+4%)
	Q18-2,1	1	3.02x10 ⁵	1.26x10 ⁷
	Q18-2,2	3	3.62x10 ⁵ (+3%)	1.46x10 ⁷ (+4%)
	Q18-2,3	3	4.50x10 ⁵ (+2%)	1.83x10 ⁷ (+1%)
	Q28-2,1	3	4.26x10 ⁵ (+4%)	1.17x10 ⁷ (+2%)
	Q28-2,2	3	4.73x10 ⁵ (+4%)	1.25x10 ⁷ (+3%)
	Q28-2,3	3	4.99x10 ⁵ (+2%)	1.31x10 ⁷ (+2%)
	Q27-1,1	3	3.61x10 ⁵ (+1%)	5.41x10 ⁶ (+4%)
	Q27-1,2	3	3.14x10 ⁵ (+3%)	4.96x10 ⁶ (+3%)
	Q27-1,3	3	3.96x10 ⁵ (+3%)	6.10x10 ⁶ (+2%)
	Q17-1,2	3	1.22x10 ⁶ (+3%)	1.53x10 ⁷ (+3%)

APPENDIX C - Data for Figures cont'd

<u>File</u>	<u>Sample</u>	<u># Readings</u>	<u>110-220oC</u>	<u>220-390oC</u>
Jul80	Q17-1,3	3	1.17x10 ⁵ (+9%)	1.71x10 ⁷ (+7%)
	Q57-1,1	1	2.28x10 ⁶	5.60x10 ⁷
	Q57-1,2	3	2.23x10 ⁶ (+3%)	5.09x10 ⁷ (+4%)
	Q57-1,3	3	1.28x10 ⁶ (+5%)	2.79x10 ⁷ (+3%)
Aug80	WR13-1,1	4	5.07x10 ⁴ (+4%)	8.36x10 ⁴ (+4%)
	WR14-1,1	4	5.63x10 ⁴ (+1%)	6.95x10 ⁴ (+13%)
	WR24-1,1	4	2.03x10 ⁵ (+1%)	1.13x10 ⁵ (+2%)
	WR54-1,1	4	4.76x10 ⁵ (+3%)	1.62x10 ⁵ (+3%)
	WR15-1,1	4	6.31x10 ⁵ (+5%)	1.54x10 ⁵ (+5%)
	WR25-1,1	4	1.57x10 ⁶ (+1%)	3.02x10 ⁵ (+2%)
	WR55-1,1	4	8.34x10 ⁶ (+7%)	1.24x10 ⁶ (+8%)
	WR16-1,1	4	6.06x10 ⁶ (+2%)	2.05x10 ⁶ (+2%)
	WR26-1,1	4	1.85x10 ⁷ (+2%)	1.72x10 ⁷ (+2%)
	WR56-1,1	4	1.38x10 ⁷ (+1%)	2.45x10 ⁷ (+2%)
	WR17-1,1	4	4.42x10 ⁶ (+1%)	1.67x10 ⁷ (+1%)
	WR27-1,1	4	5.19x10 ⁶ (+1%)	2.36x10 ⁷ (+3%)
	WR57-1,1	4	3.71x10 ⁶ (+4%)	2.34x10 ⁷ (+4%)
	WR18-2,1	4	2.43x10 ⁶ (+3%)	1.36x10 ⁷ (+2%)
	WR28-2,1	4	3.14x10 ⁶ (+2%)	2.42x10 ⁷ (+2%)
Nov80	WR13-1,2	4	3.73x10 ⁴ (+5%)	8.36x10 ⁴ (+5%)
	WR14-1,2	4	6.84x10 ⁴ (+4%)	7.43x10 ⁴ (+3%)
	24-1,2	5	1.42x10 ⁵ (+2%)	9.52x10 ⁴ (+2%)
	54-1,2	4	2.97x10 ⁵ (+5%)	1.19x10 ⁵ (+3%)
	15-1,2	4	3.93x10 ⁵ (+4%)	1.27x10 ⁵ (+3%)
	25-1,2	4	6.38x10 ⁵ (+16%)	1.86x10 ⁵ (+2%)
Dec80	55-1,2	4	2.23x10 ⁶ (+3%)	4.56x10 ⁵ (+3%)
	16-1,2	4	2.87x10 ⁶ (+3%)	1.17x10 ⁶ (+2%)
	26-1,2	4	4.31x10 ⁶ (+5%)	3.80x10 ⁶ (+3%)
	56-1,2	4	4.26x10 ⁶ (+10%)	8.03x10 ⁶ (+6%)
	17-1,2	4	2.15x10 ⁶ (+8%)	8.09x10 ⁶ (+3%)
	27-1,2	4	1.78x10 ⁶ (+6%)	7.70x10 ⁶ (+1%)
	57-1,2	2	1.48x10 ⁶ (+11%)	8.61x10 ⁶ (+9%)
	18-2,2	4	1.18x10 ⁶ (+8%)	7.79x10 ⁶ (+8%)
**Feb81	19	3	2.42x10 ⁵ (+12%)	1.44x10 ⁶ (+11%)
	19-P	3	6.48x10 ⁵ (+4%)	1.33x10 ⁶ (+6%)

*Volume measure, not weighed

**Aug79 values multiplied by 244 to account for different instrument sensitivity

APPENDIX D
Inventory of Remaining Irradiated Samples

<u>Dose Rads</u>	<u>Irradiation Date</u>	<u>Sample Data</u>	<u>Grain Size</u>	<u>Dose Rads</u>	<u>Irradiation Date</u>	<u>Sample Ident.</u>	<u>Grain Size*</u>
5x10 ²	21 Jul 80	52-1	S	5x10 ⁶	10 Jan 80	56-2	S
1x10 ³	21 Jul 80	13-2	S	"	"	56-1, 1	100-150
1x10 ³	21 Jul 80	13-1, 1	100-150	"	"	56-1, 2	50-100
		13-1, 2	50-100	"	"	56-1, 3	50
		13-1, 3	50	5 Nov 79	5 Nov 79	56-P	44-177
2x10 ³	21 Jul 80	23-1	S	1x10 ⁷	10 Jan 80	17-2	S
5x10 ³	21 Jul 80	53-1	S	"	"	17-1, 1	100-150
1x10 ⁴	31 Oct 79 79	14-1, 1	100-150	"	"	17-1, 2	50-100
		14-1, 2	50-100	"	"	17-1, 3	50
		14-1, 3	50	"	"	17-1	L
2x10 ⁴	31 Oct 79	24-1, 1	100-150	2x10 ⁷	10 Jan 80	27-2	S
		24-1, 2	50-100	"	"	27-1, 1	100-150
		24-1, 3	50	"	"	27-1, 2	50-100
5x10 ⁴	5 Nov 79	54-2	S	"	"	27-1, 3	50
	31 Oct 79	54-1, 1	100-150	"	"	27-1	L
	"	54-1, 2	50-100	5x10 ⁷	10 Jan 80	57-1, 1	100-150
	"	54-1, 3	50	"	"	57-1, 2	50-100
1x10 ⁵	5 Nov 79	15-2	S	"	"	57-1, 3	50
"	"	15-1, 1	100-150	"	"	57-P	44-177
"	"	15-1, 2	50-100	1x10 ⁸	10 Jan 80	57-1	L
"	"	15-1, 3	50	"	"	18-1	S
17 Jul 80	17 Jul 80	15-3	S	"	"	18-2, 1	100-150
2x10 ⁵	14 Dec 79	25-2	S	"	"	18-2, 2	50-100
"	"	25-1, 1	100-150	"	"	18-2, 3	50
"	"	25-1, 2	50-100	"	"	18-2	L
"	"	25-1, 3	50	2x10 ⁸	10 Jan 80	28-1	S
5x10 ⁵	14 Dec 79	55-2	S	"	"	28-2, 1	100-150
"	"	55-1, 1	100-150	"	"	28-2, 2	50-100
"	"	55-1, 2	50-100	"	"	28-2, 3	50
"	"	55-1, 3	50	"	"	28-2	L
5 Nov 79	5 Nov 79	55-P	44-177	5x10 ⁸	7 Dec 79	58-P	44-177
1x10 ⁶	14 Dec 79	16-1, 1	100-150	1x10 ⁹	3 Jul 79	19	44
"	"	16-1, 2	50-150	"	3 Jul 79	19P	44
"	"	16-1, 3	50	"	28 Mar 80	19-1	S
2x10 ⁶	14 Dec 79	26-2	S	2x10 ⁹	31 Jul 80	29-3	S
"	"	26-1, 1	100-150				
"	"	26-1, 2	50-100				
"	"	26-1, 3	50				

*S= Solid Sample
L= Leftover powder,
original grain size
distribution, perhaps deficient
in fines.

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