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THE INFLUENCE OF CLIMATE AND RELIEF ON LITHIC FRAGMENT ABUNDANCE IN MODERN FLUVIAL SANDS OF THE SOUTHERN BLUE RIDGE MOUNTAINS, NORTH CAROLINA

By

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ABSTRACT

THE INFLUENCE OF CLIMATE AND RELIEF ON LITHIC FRAGMENT ABUNDANCE IN MODERN FLUVIAL SANDS OF THE SOUTHERN BLUE RIDGE MOUNTAINS, NORTH CAROLINA

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Chemical weathering imprints are observed in sediments derived from a variable humid climate in the Coweeta basin, North Carolina. Of the four grain types studied; monocrystalline quartz, polycrystalline quartz, mica, and lithic fragments, these imprints are best developed in the lithic fragments because these are the grains that are most sensitive to chemical degradation. The extent of chemical weathering is a function of the duration and intensity of chemical weathering in the source area. In the Coweeta basin, the intensity of chemical weathering is directly related to the climatic variability across the basin, while duration of chemical weathering is inversely related to the average topographic slope of a watershed. Therefore, in the Coweeta basin, watersheds with low slope and high discharge per unit area have the highest extent of chemical weathering, and sediments derived from these watersheds contain the lowest percentage of lithic fragments.

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INTRODUCTION

The effects of provenance upon the composition of sands and sandstones have been a subject of great interest for many years. Obviously, the composition of the parent rock has a large influence upon the sediments which are derived from it; however, other factors also greatly affect the composition of the sediments eroded from a source area. Mann and Cavaroc (1973), Young et al. (1975), and Mack and Suttner (1977) have all shown that the composition of the sediments is largely affected by the climate in the source area. Specifically, Young et al. (1975) showed that lithic fragments are relatively more abundant in sediments derived from source areas with an arid climate than those derived from source areas with a humid climate. Young et al.(1975), and Suttner et al. (1981) suggested that more intense chemical weathering of lithic fragments in the soils of the more humid source area accounts for the lesser abundance of lithic fragments relative to sediments derived from an arid source.

The purpose of this study is to examine in more detail the relationship between the lithic fragment abundance in Holocene stream sediments and the climatic variability within a source area. This study differs from previous studies of this nature (Young et al. 1975; Basu, 1976; Mack and Suttner, 1977)) in three fundamental ways. First, this study is confined to one small, topographic basin with considerable climatic variability across its length. This provides better control on factors such as the distance of sediment transport and source rock variability which otherwise might influence the results.

Secondly, this study examines the effect of chemical weathering on sand size sediments within a variable humid climate. Unlike previous studies (e.g. Young et al., 1975) which have compared only the extreme climatic conditions of arid and humid, this study will focus on a range of humid rainfall conditions (170-250cm/yr), to determine whether climatic imprints on sediment composition can be differentiated at this more refined level.

Thirdly, this study specifically investigates the effect of climate on lithic fragments in the sand size fraction of the sediments, since these are thought to be the best indicators of climatic variability (Basu, 1976). However, other mineral grains in the samples are also studied for evidence of climatic imprinting.

The results of this study indicate that, in a controlled study area where the effect of parent rock variability and transportation are minimal, climate alone does not control the composition of the sediments. Instead, a combination of the climate and topographic slope exert an integrated weathering imprint upon the sediments. Of the grain types studied in the samples, lithic fragment abundance best reflects this weathering imprint from the source area.

PREVIOUS WORK

For over the last decade, numerous studies have investigated the effect of climate on the petrology of Holocene sands (Mann and Cavaroc, 1973; Young et al., 1975; Basu, 1976; Mack and Suttner, 1977; and Suttner et al., 1981). Young et al. (1975) observed climatic imprinting from the source area in recent fluvial sediments derived from low-rank metamorphic, high-rank metamorphic and plutonic source rocks. They found that major petrographic distinctions exist in sediments derived from the same source rock types between the humid southeastern U.S. and the arid northwestern U.S. Lithic fragments were much more abundant in all the sediments derived from the arid climate (see figure 1), while monocrystalline and polycrystalline quartz were more abundant in sediments derived from the more humid climate. Young et al. (1975) explained these results by suggesting that rock fragments are easily destroyed by rigorous chemical weathering in a more humid environment, whereas quartz (mono- or polycrystalline) is much more resistant to chemical weathering and actually increases in relative abundance in the more humid climates because of the release of quartz grains from the weathering of the lithic fragments. Basu (1976) therefore concluded that, of the sand size fraction in fluvial sediments, lithic fragments are the best climatic indicators since

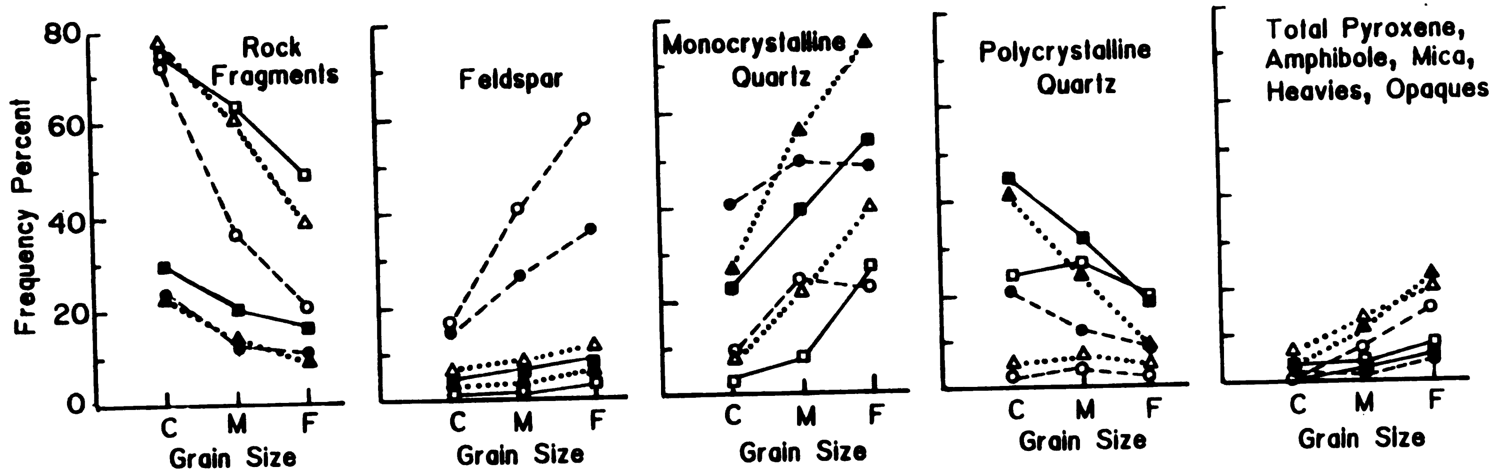


Figure I. Variation in composition of Holocene fluvial sand in the size range -1ϕ to 4ϕ. Samples from the semi-arid northwest U.S. : (□—□) - low-rank metamorphic, (△···△) - high-rank metamorphic, and (o--o) - plutonic. Samples from the humid southeast U.S. : (■—■) - low-rank metamorphic, (▲···▲) - high-rank metamorphic, and (●--●) - plutonic (From Young et al., 1975).

they are most sensitive to destruction by chemical weathering.

To accurately interpret the effect of climate on lithic fragment abundance in fluvial sediments, other factors which might affect the composition of these sediments must also be evaluated. Young et al. (1975) and Suttner et al. (1981) studied the effect of transportation upon sediments by comparing sand-size stream sediments to the sand-size fraction of the soil from both a gneissic and plutonic soucre area. They found that the sand fraction of the soil and fluvial sand from the same parent rock had very similar compositions (see Figure 2) and concluded that the effect of transportation over short distances is relatively minor in fluvial sands in comparison to the importance of chemical weathering in the source area. Basu (1976) concurred and noted that even in high gradient streams, the effect of short fluvial transportation on igneous rock fragments is negligible. Further, Breyer and Bart (1978) suggested that granitoid rock fragments can undergo more than 600 km of transportation with very little physical breakdown.

The mechanical durability of schistose rock fragments is more questionable. Cameron and Blatt (1971) found that schistose lithic fragments are easily broken down in relatively short distances of transport. However, Mann and Cavaroc (1973) found that although micaceous rock fragments are drastically reduced by chemical weathering in the

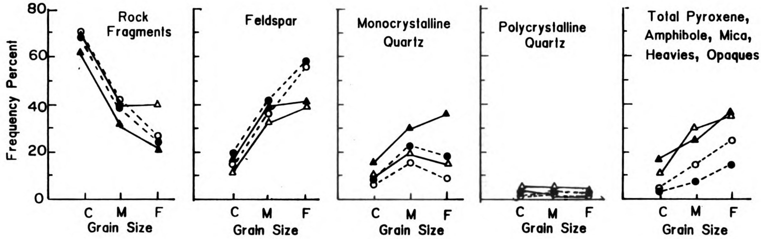


Figure 2. Comparison of size-composition plots for soils and Holocene fluvial samples. Soil samples: (△—△) -gneiss, and (o--o) -plutonic. Fluvial samples (▲—▲) -gneiss, and (●--●) -plutonic (From Young et al., 1975).

source area, they showed no detectable effects from transportation.

The effect of parent rock lithology on fluvial sand composition has also been studied by several workers. In particular, Mann and Cavaroc (1973) compared Holocene fluvial sands released from granitic, metamorphic and first cycle sedimentary source rocks and found that the sediments derived from each were discernable in subtle ways. The first cycle sedimentary rock was derived from a metamorphic and granitic source so that the sediments from it differed from the others only in that they contained fewer labile grains and were more enriched in quartz. The sediments derived from the metamorphic source could be distingushed from the granitic sands by the higher percentage of polycrystalline quartz and gneissic lithic fragments in the coarse sands, and the extremely high percentage of monocrystalline quartz in the fine grained sands.

Basu et al. (1975) showed that the crystalline source rock for a sediment can be determined by plotting relative percentages of (1) undulose quartz, (2) non-undulose quartz, (3) polycrystalline quartz with two to three crystals per grain, and (4) polycrystalline quartz with more than three crystals per grain, on a diamond diagram (see figure 3). Sediments derived from a low rank metamorphic source rock tended to have more undulatory quartz, and polycrystalline quartz with greater than three crystals per grain. Sediments derived from a plutonic

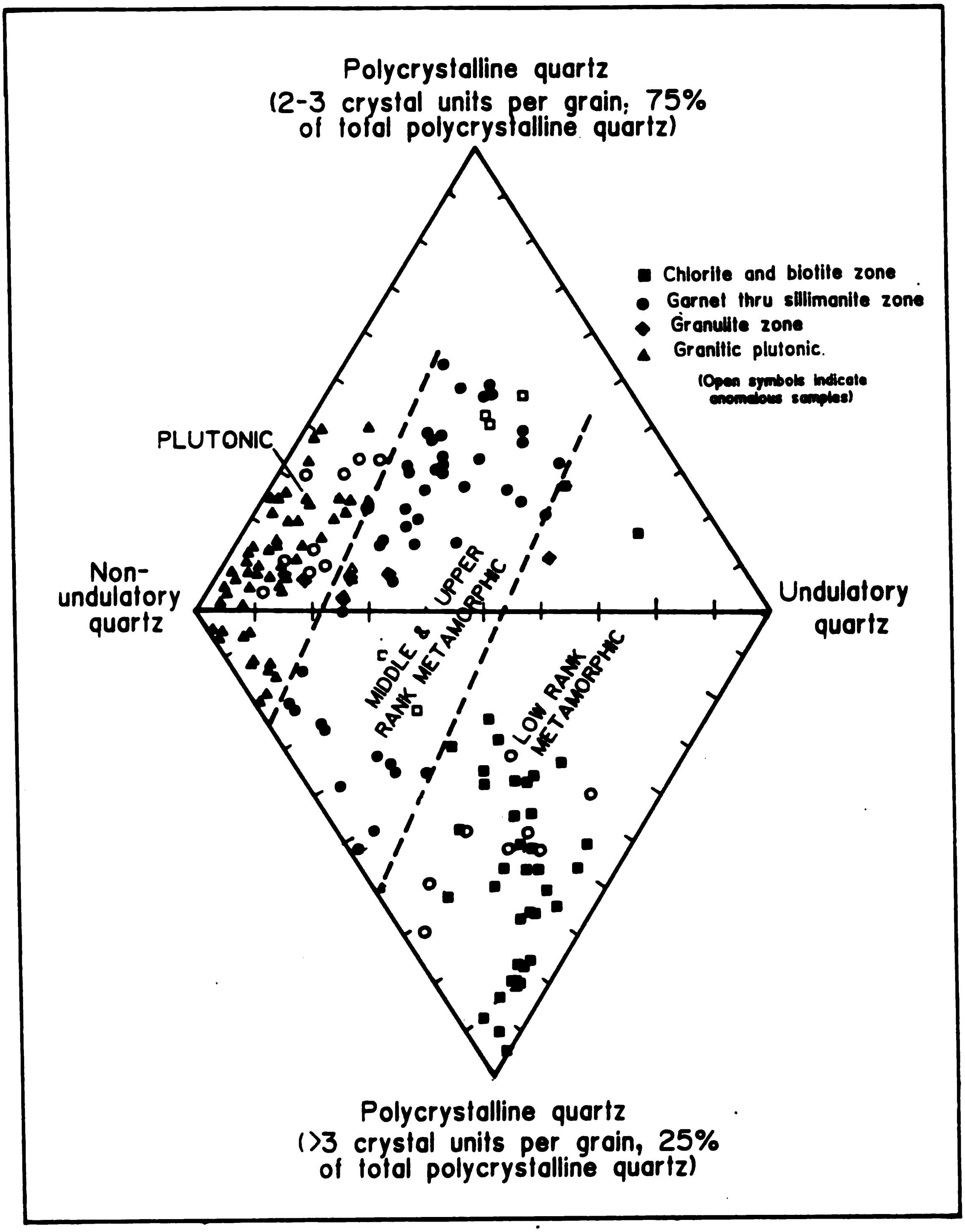


Figure 3. Four variable plot of quartz population in Holocene sand derived from source rocks indicated by symbols (From Basu et al., 1975).

source have more non-undulatory quartz, and polycrystalline quartz with less than three crystals per grain. Sediments from a middle to high rank metamorphic source have monocrystalline and polycrystalline quartz which plots between the quartz from the plutonic and low rank metamorphic sources.

STUDY AREA

The study area for this project is the Coweeta Hydrologic Laboratory, located in the Blue Ridge Mountains of Southwestern North Carolina (see Figure 4). The laboratory is a 1625 hectare basin managed by the U. S. Forest Service, and is used primarily to investigate the effect of varying practices of forest management on the hydrology and nutrient flow in the basin (Douglass and Swank, 1975; and Swank and Douglass, 1977).

The area was chosen for this study principally because of the large variability of precipitation across the basin. More important than rainfall, however, the stream discharge from the areas of high precipitation is over double that from areas of low precipitation and actually represents the water involved in the chemical weathering of the source rock.

The Coweeta Hydrologic Laboratory is very well suited to this study because of the large amount of background information and data that is available. This includes stream discharge and precipitation data for most of the individual watersheds (USDA Forest Service, unpublished data), detailed geochemistry of the watersheds, including mineral weathering data (Velbel, 1984a), and a complete geologic map (Hatcher, 1980) and detailed descriptions of geologic units present in the Coweeta basin (Hatcher, 1971, 1974, 1976, 1979).

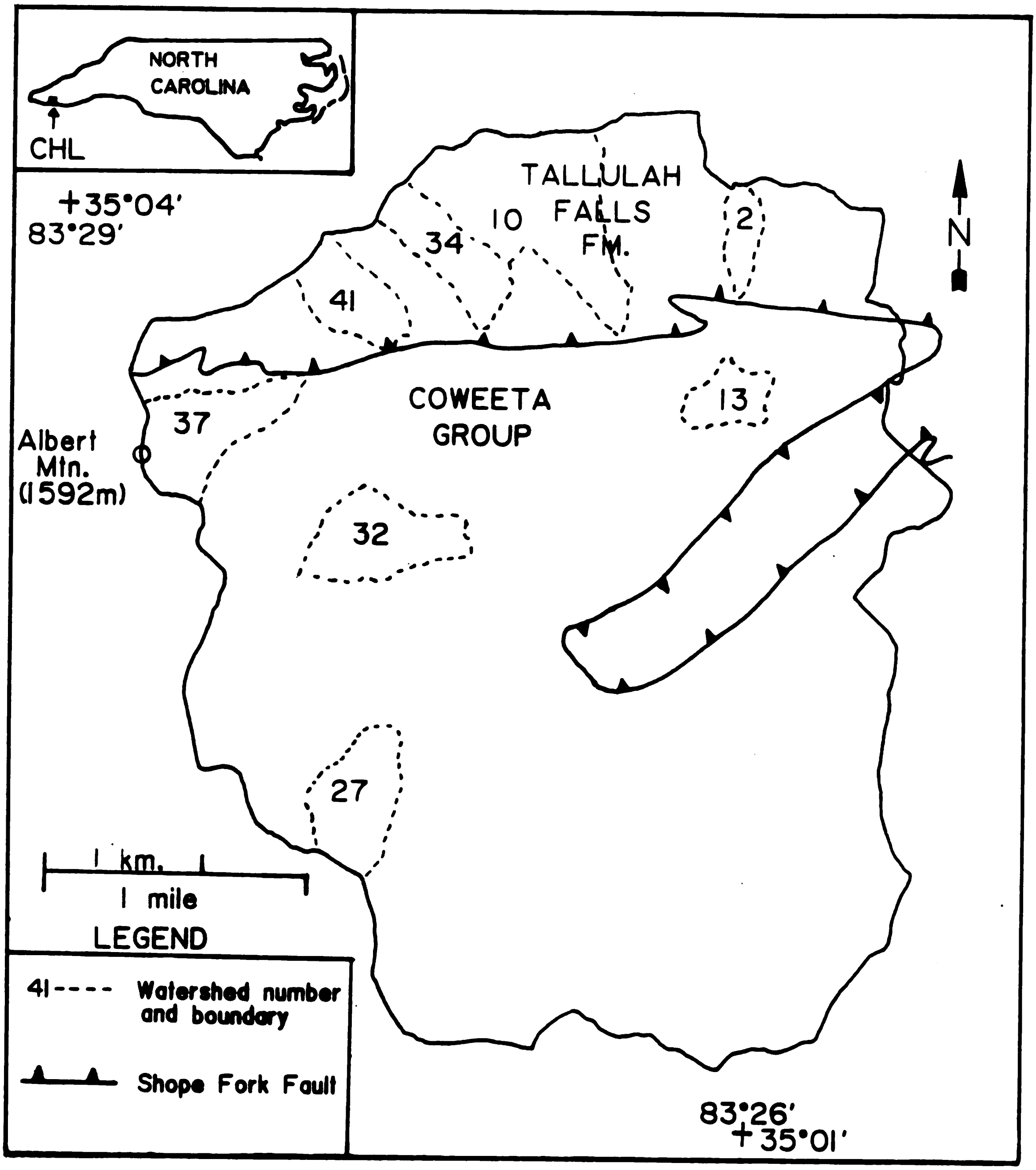


Figure 4. Map of the Coweeta Hydrologic Laboratory

TOPOGRAPHY

The relief in the Coweeta basin is quite rugged with elevations ranging from 5200 feet (1585 meters) at Albert Mountain on the western border to 2200 feet (670 meters) in the valley of Coweeta Creek in the east. The average slope across this part of the whole basin is 36% ; however, average slopes in the individual watersheds studied are much higher, ranging from 50% to 100% (see Table 1. Note: the discharge/slope column will be discussed in the Discussion section).

CLIMATE AND HYDROLOGY

Average annual precipitation at the Coweeta Hydrologic Laboratory is among the highest in the eastern United States, with precipitation ranging from 67.0 inches (170 centimeters) at the lower elevations to 98.5 inches (250 centimeters) at the higher elevations (Swank and Douglass, 1975). The precipitation is distributed fairly evenly throughout the year with only a minor amount falling as snow. The mean annual temperature for the area is 55°F (12.8°C), with average maxima and minima of 92°F (33°C) and 1°F (-17°C) respectively (Douglass and Swank, 1975).

Streamflow in the basin is perennial, ranging from 27 to 68 inches (69 to 173 centimeters) per unit area per year, and is a function of precipitation and evapotranspiration within each individual watershed. Base flow is sustained

Table 1. Data for watersheds used in study.

WS No.	Prec[1]	Disc[2]	Slope[3]	Disc/Slope	Bedrock[4]
2	68	32	81	40	Tallulah Falls
10	-	42	53	80	Tallulah Falls
34	77	47	60	78	Tallulah Falls
41	81	53	90	59	Tallulah Falls
13	74	42	56	75	Coweeta Group
27	94	68	82	83	Coweeta Group
32	85	55	51	108	Coweeta Group
37	88	64	100	64	Coweeta Group

1. Average annual precipitation (inches/unit area) calculated over a 20 year period from 1954 to 1973 for each watershed (USDA Forest Service, unpublished data).

2. Average annual discharge (inches/unit area) calculated over the interval that each watershed was monitered (USDA Forest Service, unpublished data).

3. Average slope (%) calculated from the maximum relief divided by the maximum length of each watershed.

4. Taken from Hatcher (1980).

by extended drainage of unsaturated soil and saprolite (Hewlett, 1961) so that by late summer flows tend to be lowest and most stable. Direct runoff only occurs in disturbed watersheds and is usually less than 10% of total runoff (Swank and Douglass, 1977).

BEDROCK GEOLOGY

The study area is situated in the metamorphosed Blue Ridge of North Carolina. The bedrock consist of two Upper Precambrian lithostratigraphic units, the Tallulah Falls Formation and the Coweeta Group, which are juxtaposed along the Shope Fork Thrust Fault (Figure 4). The Tallulah Falls Formation, the older of the two units, consist predominantly of metagraywackes, muscovite and biotite schists and amphibolites (Hatcher, 1971,1976). A list of the mineral assemblages and lithologies in the Tallulah Falls Formation is given in Table 2.

Hatcher (1979) divides the Coweeta Group into three formations. The oldest of these formations is the Persimmon Creek Gneiss, a massive oligoclase-quartz-biotite gneiss with minor amounts of metasandstone and schist near the top of the unit. The Coleman River Formation overlies the Persimmon Creek Gneiss and is composed predominantly of metaarkose and quartz-feldspar gneiss with interlayers of pelitic schist. The Ridgepole Mountain Formation is the uppermost unit of the Coweeta Group and contains the

Table 2. Lithologies and mineral assemblages in the Tallulah Falls Formation (from Hatcher, 1976).

Member/Lithology	Assemblage*
Quartzite-Schist	
Quartzite	Q M P Mi B C Mt Z T E
Schist	M B Q P Mt T
Graywacke-Schist	
Metagraywacke	Q B P M Mt S Z A T E G
Schist	M B Q P Mt
Garnet-Aluminous Schist	
Aluminous Schist	M G Q K (or Si) P B Mt
Metagraywacke	Q B P M Mt S Z A T E G
Amphibolite	H P Q E Mt G S A B
Graywacke-Schist Amphibolite	
Metagraywacke	Q B P M Mt S Z A T E G
Schist	M B Q P Mt
Amphibolite	H P Q E Mt G S A B

Q - Quartz
P - Plagioclase
Mi - Microcline
M - Muscovite
B - Biotite
Si - Sillimanite
S - Sphene
E - Epidote (or Clinozoisite)
Mt - Magnetite
H - Hornblende
A - Apatite
T - Tourmaline
Z - Zircon
G - Garnet

* Minerals listed in order of decreasing abundance.

greatest variety of lithologies, including pelitic and biotite schists, clean quartzites to muscovite-chlorite quartzites and metasandstones (Hatcher, 1979). A list of the mineral assemblages and lithologies in the Coweeta Group is given in Table 3.

The major difference between the Tallulah Falls Formation and the Coweeta Group is that the sedimentary protoliths for the Tallulah Falls Formation were less mineralogically mature than for the Coweeta Group (Hatcher, 1979).

GEOCHEMISTRY

Velbel (1985) suggested that the dissolved load of the streams in the Coweeta basin is affected by two variables, parent rock type and flushing rate. He contends that the greater the maturity of the parent rock protolith, as in the Coweeta Group rocks, the lower the abundance of weatherable minerals, and thus the lower the concentrations of dissolved weathering products in the stream water. However the Tallulah Falls protoliths are mineralogically less mature, so that these rocks have more weatherable minerals, resulting in higher dissolved concentrations in streams draining the Tallulah Falls Formation relative to streams draining the Coweeta Group rocks for watersheds with comparable discharges. The dissolved load in the streams in the Coweeta basin is also affected by the flushing rate at which the water is percolating through the watersheds. Velbel (1985) suggests that with a high

Table 3. Lithologies and mineral assemblages in the Coweeta Group (from Hatcher 1979).

Unit/Lithology	Assemblages*
Ridgepole Mountain Formation	
Biotite- Garnet Schist	B M G C Q P
Quartzite	Q M C E G B St Mt
Pelitic Schist	M B G Ky C
Coleman River Formation	
Metasandstone	Q P M B E C G Mt
Quartz-Feldspar Gneiss	Q P M B G
Pelitic Schist	M B Q G Ky St Mt
Persimmon Creek Gneiss	
Biotite Gneiss	P Q B M E G C Ap Mt
Metasandstone	Q P M B E C G Mt
Pelitic Schist	M B Q G Ky St Mt

Q - Quartz
M - Muscovite
B - Biotite
G - Garnet
P - Plagioclase
C - Chlorite
K - Kyanite
St - Staurolite
E - Epidote (or Clinozoisite)
Mt - Magnetite
A - Apatite

* Minerals listed in order of decreasing abundance.

flushing rate, there is less opportunity for the water to acquire solutes, so that the limiting factor may be the rate at which cations are contributed to the percolating solution.

METHODS

FIELD SAMPLING

Sand-size stream sediments were collected across the Coweeta basin in two transects, one sampling sediments derived from the Tallulah Falls Formation and the other for sediments derived from the Coweeta Group. These transects ran roughly East-West, with elevation and watershed discharge increasing to the West. Table 1 lists stream discharge, average topographic slope, and bedrock type for the watersheds which were sampled. No watersheds were used in this study that were recently disturbed or altered, so the effects of varied biota on chemical weathering in the source area are minimal.

Each watershed was sampled 40 to 60 feet above the weir at 3 intervals 20 to 30 feet apart to test for homogeneity of the sediments. To minimize the effect of transportation, all samples were collected from streams which are first or second order and less then one-half mile in length.

SAMPLE PREPARIATION AND POINT COUNTING

The samples were wet sieved into three fractions, coarse (-1ϕ to 1ϕ), medium (1ϕ to 2ϕ) and fine (2ϕ to 4ϕ). Portions of each fraction were vacuum impregnated with epoxy and thin sectioned. Samples were not stained for potassium feldspar determination since its occurrence in the parent rocks is minimal. Each thin section was then point counted (Chayes, 1949) for monocrystalline quartz, polycrystalline quartz, lithic fragments, mica, garnet, plagioclase, heavy minerals and others at about 300 points per thin section . Lithic fragments are defined following Suttner et al. (1981). Modal percentages of monocrystalline quartz, polycrystalline quartz, lithic fragments, and mica were then recalculated to 100 percent for the remaining analysis.

TEST FOR EFFECT OF TRANSPORTATION

Garnet grains have been shown to develope a gibbsite-goethite weathering rind in saprolites from the Coweeta basin (Velbel, 1984b). These rinds are relatively fragile and can withstand little high-energy transportation. To determine the effect of transportation upon the sediments, garnets were counted as having complete rinds, partial rinds, or no rinds in the coarse sediment fraction from each watershed.

TEST FOR PARENT ROCK HOMOGENEITY

Parent rock homogeneity between watersheds would have a large effect upon the sediment derived from these areas. For example, if the parent rock in watershed X was 80% schist and 20% quartzite while the parent rock in watershed Y was 20% schist and 80% quartzite, then one would expect to see major differences in the petrology of the sediments between these two areas.

To determine roughly the degree of homogeneity of the parent rock between watersheds underlain exclusively by the Tallulah Falls Formation or the Coweeta Group rocks, a simple test for parent rock homogeneity was devised by the author following the work of Young et al. (1975). Approximately 300 monocrystalline quartz grains from the medium sand size fraction of each watershed were point counted on a flat stage and classified as either undulose ($>5^{\circ}$ extinction) or nonundulose ($<5^{\circ}$ extinction). These relative percentages for each watershed were compared between sediments derived from the same parent rock to determine roughly the homogeneity of bedrock within the Coweeta Group and the Tallulah Falls Formation.

RESULTS

EFFECTS OF PARENT ROCK HOMOGENEITY AND TRANSPORTATION

The results of the tests for parent rock homogeniety are given in Table 4. These are presentedn as the percent undulose quartz to total monocrystalline quartz in the medium-sized sands from sediments across the Coweeta basin. Samples from watersheds 2, 41, 10 and 34 were derived from parent rock consisting of only the Tallulah Falls Formation, while samples 13, 27, 32, and 37 were derived from only the Coweeta Group parent rock. The percent undulose quartz to total monocrystalline quartz in the medium-sized sand fraction of the sediment draining the Tallulah Fall Formation parent rocks varies by only 3% among the four watersheds 2, 41, 10, and 34, while among the four watersheds (13, 27, 32, 37) draining the Coweeta Group rocks, the percent undulose to total monocrystalline quartz in the medium-sand sized fraction varies by only 4%. However, the percent undulose quartz varies by over 20% between sediments derived from the Tallulah Falls Formation and Coweeta group rocks.

The results of the test for the effect of transportation show that a large number of all the garnets from the watershed draining both Tallulah Falls Formation rocks (ws 2,41,10,34) and Coweeta group rocks (ws 13,27,32,37) have whole or partial gibbsite-goethite weathering rinds (see Table 5). The average relative percent of garnets with

Table 4. Unudulosity of quartz as an indicator of parent rock homogeniety.

Tallulah Falls Watersheds

Watershed No.	Undulose	Nonundulose
WS#2	49%	51%
WS#10	47%	53%
WS#34	46%	54%
WS#41	46%	54%
	Ave. 47%	Ave. 53%

Coweeta Watersheds

Watershed No.	Undulose	Nonundulose
WS#13	28%	72%
WS#27	27%	73%
WS#32	24%	76%
WS#37	28%	72%
	Ave. 27%	Ave. 73%

Table 5. Weathering rinds on garnets as indicators of the effect of transportation.

Tallulah Falls Watersheds

Watershed No.	Whole Rind	Partial Rind	No Rind
WS#2	45%	33%	22%
WS#10	48%	43%	9%
WS#34	46%	42%	12%
WS#41	43%	31%	26%

Coweeta Watersheds

Watershed No.	Whole Rind	Partial Rind	No Rind
WS#13	60%	29%	11%
WS#27	52%	32%	16%
WS#32	52%	33%	15%
WS#37	39%	34%	27%

whole rinds in sediments derived from the Tallulah Falls Formation rocks is 45%, with 83% of the garnets showing at least a partial rind. For the sediments derived from the Coweeta group rocks, the average relative percent of garnets with a complete weathering rind is slightly over 50%, while 83% of these garnets show a partial rind or more. The occurrence of garnets with partial or no rinds does not necessarily imply that these were eroded off during transportation since not all garnets in the weathering profile form gibbsite-geothite weathering rinds. These rinds form primarily in the saprolite horizon of the weathering profile but are often chemically removed once the garnets migrate into the soil horizon (Velbel, 1984b).

RESULTS OF POINT COUNTING

The results of the point counts are compiled in Appendix A. Modal percents of lithic fragments, monocrystalline quartz, polycrystalline quartz, and mica were recalculated to 100% and these values are used in the remaining analyses. The average modal abundance of each grain type was calculated from the point counts of the three samples taken from each watershed. These were then plotted against grain-size (coarse, medium, and fine) following the work of Young et al.(1975) for each group of sediments derived either from the Tallulah Falls Formation or Coweeta Group rocks. Of the four grain types plotted, only the modal percentage of mica shows a relationship to the climatic variability in the source area for both the Tallulah Falls and Coweeta Group sediments. Climatic variability is measured not as precipitation per unit area as done in most previous studies (Young et al., 1975; Basu, 1976; and Mack and Suttner, 1977), but rather as stream discharge per unit area per year since this more accurately represents the water which is involved in the chemical weathering of the source rock.

The discharge per unit area for watersheds underlain by Coweeta Group rocks increases from 13 to 32 to 37 to 27; this corresponds to an increase in the modal abundance of mica in these sediments (Figure 5) except in the fine fraction of watershed 27. The same basic relationship holds between discharge and the micas in the sediments derived from the Tallulah Falls Formation rocks; as the discharge per unit area increases between watersheds, the modal abundance of mica in the sediments also increases except for the medium and fine fractions in watershed 41 (Figure 6).

From Figures 5 and 6, there is no other obvious relationship between the climatic variability (discharge per unit area) and the modal abundance of monocrystalline quartz, pollycrystalline quartz or lithic fragments.

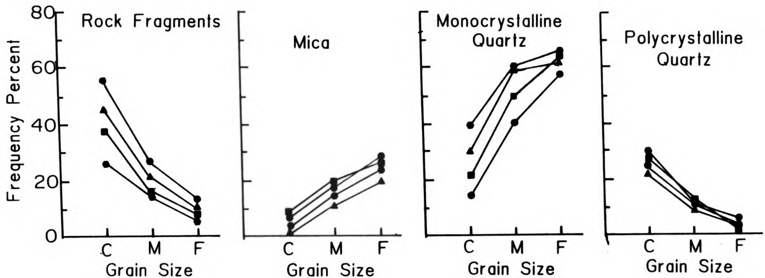


Figure 5. Variation in composition of fluvial sand from four watersheds draining the Coweeta Group bedrock.

	ws#	discharge	slope	disc./slope
●	37	64	100	64
▲	13	42	56	75
■	27	68	82	83
⬢	32	55	51	108

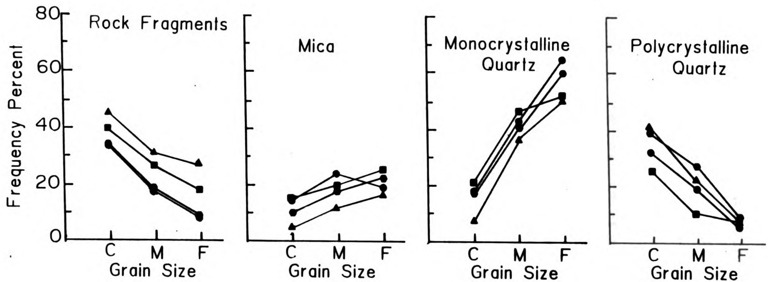


Figure 6. variation in composition of fluvial sand from four watersheds draining the Tallulah Falls Formation bedrock.

	ws#	discharge	slope	disc./slope
▲	2	32	80	40
■	41	53	90	59
⬟	34	47	60	78
●	10	42	53	80

DISCUSSION

ARE SEDIMENT TRANSPORT AND PARENT ROCK VARIABILITY SIGNIFICANT FACTORS?

The purpose of addressing this question is to determine if climatic variability is the only factor affecting the sediment composition from a particular geologic unit, e.g., Coweeta Group or Tallulah Falls Formation, in the Coweeta Basin. After studying the results of these tests, this author believes that other factors do affect the sediment composition, but that these effects are relatively minor in comparison with the effect of chemical weathering in the source area.

Numerous other studies (Mann and Cavaroc,1973; Young et al., 1975; and Basu, 1976) have concluded that the physical effects of short distances of transportation, up to several miles, are relatively minor in fluvial sands. The overall results of this study's test for the effect of transportation on sediments within the Coweeta basin also show that little mechanical breakdown has occurred between the source area and the sampling stations. This conclusion is based on the occurrence of very fragile gibbsite-goethite weathering rinds on garnets in sediments within the sampling area, less than one-half mile from the source areas, but at distances of three miles or greater downstream, weathering rinds are completely absent on any garnets (Velbel, personal communication). This suggests that mechanical breakdown by transportation within the study area is minimal, but that continued transportation outside the study area is affecting the most labile grains such as these gibbsite-goethite weathering rinds.

On the other hand, by comparing the discharge per unit area of a watershed to the relative percent of garnets with complete weathering rinds, it appears that some mechanical breakdown by transportation is occurring in the study area. In watersheds with high discharges and slopes there are fewer garnet grains with complete weathering rinds (see Table 5; e.g., watersheds 37 and 41) than in the other watersheds studied. The author interprets this as indicating that mechanical destruction of the gibbsite-goethite weathering rinds on garnets occurs more rapidly in watersheds with higher energy streams.

This, however, does not necessiarly mean that other detrital grains are also affected by short fluvial transport. The fact that these rinds are totally absent on garnets in the sediments three miles from the source area while other labile grains such as lithic fragments still occur in abundance suggests that these gibbsite-goethite rinds are ultra-sensitive to mechanical degradation and that limited transport may affect them without affecting other detrital grains. If, in fact, these rinds are ultrasensitive to mechanical degradation, then the occurrence of partial or whole gibbsite-goethite weathering rinds on 83% of the garnets observed would imply that the overall effect of fluvial transportation in the study area is negligible.

The influence of parent rock variability upon the sediments is much less certain. From Tables #2 and #3, it can be seen that the individual lithologies in both the Coweeta Group and the Tallulah Falls Formation are quite varied. However, the question of parent rock variability is not concerned with the diversity of lithologies within a major unit, but rather, whether these lithologies are distributed homogeneously throughout that unit. Obviously the best way to determine this would be to compile a detailed lithologic map of both the Coweeta Group and Tallulah Falls Formation in the Coweeta basin. This, however, is not feasible, since a thick soil-saprolite weathering profile covers most of the bedrock, and intense structural deformation has caused numerous repeated sections so that estimating lithologic abundances and distributions is very difficult. Therefore an alternative method was applied which used the undulosity of monocrystalline quartz grains in the sediments as a very crude indicator of parent rock homogeneity.

Although the degree of undulosity in quartz is governed not only by the lithology but also by the metamorphic grade and deformational history of the rock, the result of this test suggests that some sort of homogeneity exists within each of the two major lithologic units that does not exist between these groups. This is supported by the uniformity of the percent undulose quartz in the sediments between watersheds underlain by one geologic unit, either the Tallulah Falls Formation or the Coweeta Group. However, this uniformity does not exist when comparing the percent undulose quartz between the two major geologic unit. As stated above, undulosity is not directly related to lithologic type. However, both quartz undulosity and metamorphic lithologies are directly related to the deformational history, degree of metamorphism, and protolithic types of the unit, so that indirectly, the uniformity of undulose quartz in a lithologic unit may roughly estimate the homogeneity of the parent rock. Further detailed studies need be done to confirm this preliminary result.

DO CLIMATIC IMPRINTS EXIST IN THE SEDIMENTS FROM THE COWEETA BASIN?

The results of the plots of modal abundance of grain type to grain size indicate that only the mica grains seem to be affected by the climatic variability (discharge) across the Coweeta basin. This contradicts the original hypothesis that lithic fragments are the most sensitive to climatic variability. To resolve this contradiction, the specific factors which are affecting the sediment composition in the Coweeta basin must first be examined. The effects of transportation and parent rock homogeniety have already been discussed in the previous section; the affect of climate on sediment composition will now be examined in more detail. As previously mentioned, discharge per unit area for each watershed more closely represents the effect of climate on weathering in the source area since this is the water which actually interacts with the soil, saprolite, and parent rock. Precipitation would include not only the water which is discharged from the watershed, but also water which is recycled as evapotranspiration without ever reaching the weathering horizon.

Secondly, it is very important to realize that in a study of this nature where the effects of transportation and parent rock variability are considered minimal, the modal abundances of grain types reflect the total amount of chemical weathering which occurs in the source area, of which climate is only a part. It has been shown that the extent of chemical weathering, as measured by chemical or mineralogical changes, is dependant upon 1) the intensity of the weathering, and 2) the duration over which the weathering occurs (Krynine, 1942; Pettijohn et al., 1972; and Suttner et al., 1981). In its simplest form, the relationship is as follows:

DURATION X INTENSITY = EXTENT

Franzinelli and Potter (1983) showed that quartz arenite sands could be produced from granitic bedrock in a low relief, humid climate region of the Amazon basin by chemical weathering alone. Likewise in the Coweeta basin, watersheds with high discharges and low topographic slopes would have the highest extent of chemical weathering, while low discharge, high relief watersheds would have the lowest extent of chemical weathering. The intensity of chemical weathering in the Coweeta basin is largely dependent upon the climate, while the duration of weathering appears to be inversely related to the relief in the source area since high relief areas would have higher erosion rates and thus reduce the residence time that material is in the weathering profile. Relief is measured here as the average topographic slope (%) across the length of each watershed. The equation for the extent of chemical weathering in watersheds from the Coweeta basin can then be written as

1/SLOPE X DISCHARGE/UNIT AREA = TOTAL CHEMICAL WEATHERING

The total chemical weathering for each watershed was then plotted against the modal abundance of each grain type. Plots were also constructed of average watershed slope versus modal abundance and discharge per unit area versus modal abundance of each grain type (Appendix B). Linear regressions were calculated for each grain size (coarse, medium, and fine) for all plots with correlation coefficients, slopes, and y intercepts given in Table 6. These results showed that of all of the plots, the best

Table 6. Correlarion coefficients (r), slopes (a), and y intercepts (b) for linear regressions through each size fraction of grain type versus discharge, slope and discharge/slope.

SEDIMENTS DERIVED FROM THE COWEETA GROUP SOURCE ROCK

	Discharge			Slope			Discharge/Slope		
	r	b	a	r	b	a	r	b	a
Mono Qtz									
Coarse	56.0	58.3	-.55	93.0	59.9	-45.9	86.0	-17	.52
Medium	68.0	78.4	-.45	95.0	75.1	-31.4	70.0	28.9	.28
Fine	28.0	69.7	-.12	78.0	74.8	-16.4	78.0	46.5	.20
Poly Qtz									
Coarse	49.7	11.5	.28	0.0	27.8	-.5	44.5	14.7	.15
Medium	44.0	5.8	.09	40.5	7.9	4.0	18.7	12.8	-.02
Fine	28.0	0.5	.03	18.9	2.9	1.0	44.7	6.0	-.03
Mica									
Coarse	76.6	-10.0	.27	53.7	-1.9	9.4	10.0	5.5	-.01
Medium	82.0	-1.5	.31	58.6	8.3	11.2	30.0	18.3	-.02
Fine	79.9	12.6	.19	71.4	17.4	8.6	15.1	25.4	-.02
Lithics									
Coarse	0.0	40.0	.01	66.4	14.1	37.0	96.8	95.6	-.66
Medium	7.7	18.2	-.03	67.2	9.6	14.5	84.9	38.6	-.23
Fine	17.0	12.3	-.05	51.3	4.8	6.8	91.9	22.1	-.15

SEDIMENTS DERIVED FROM THE TALLULAH FALLS SOURCE ROCK

	Discharge			Slope			Discharge/Slope		
	r	b	a	r	b	a	r	b	a
Mono Qtz									
Coarse	69.8	1.46	0.38	8.90	16.1	2.46	35.6	12.0	0.91
Medium	89.0	23.3	0.40	36.7	34.8	8.51	22.8	37.7	0.05
Fine	22.8	48.1	0.20	80.0	82.5	-36.1	81.9	34.8	0.34
Poly Qtz									
Coarse	86.3	62.8	-.67	43.5	45.8	-17.3	14.5	37.0	-.05
Medium	64.0	40.1	-.48	70.0	38.1	-26.9	22.6	13.9	.08
Fine	16.4	6.7	-.24	7.0	6.0	-.59	0.0	5.7	0.0
Mica									
Coarse	91.1	-13.4	.53	3.1	8.9	1.1	51.1	.6	.14
Medium	59.5	1.5	.35	39.2	25.1	-11.8	68.5	4.5	.19
Fine	54.0	8.2	.28	18.1	16.8	4.7	18.7	17.3	.05
Lithics									
Coarse	54.0	49.3	-.24	60.1	29.1	13.8	85.8	50.5	-.18
Medium	39.9	36.2	-.30	78.8	1.9	30.1	92.4	44.3	-.33
Fine	43.2	35.4	-.43	78.5	-6.9	33.4	99.1	42.1	-.39

correlation exists between the modal abundance of lithic fragments and the total chemical weathering for both the Tallulah Falls sediments (Figure 7) and the Coweeta Group sediments (Figure 8). These plots show that as the total chemical weathering increases, the modal percent lithic fragments in all three size fractions decreases for both the Tallulah Falls and the Coweeta Groups sediments. This is the expected result since lithic fragments are considered the most labile grains (Basu, 1976) of those counted in this study and therefore would be the most susceptible to chemical weathering in the source area.

This relationship could not be due to mechanical degradation during transportation since lithic fragment abundances decrease with increasing discharge and decreasing slope. If transportation were affecting the sediments, lithic fragment abundance would decrease with both increasing discharge and increasing slope.

Numerous reasons may exist why only the lithic fragments in the sediments reflect the extent of chemical weathering. Foremost is the fact that polyminerallic grains have heterogeneous crystal boundries which are avenues for fluid movement and eventually cause physical breakdown of these grains. This would be especially true in foliated, metamorphic rocks where planar and non-planar crystals, e.g., mica and quartz respectively, have physically weak crystal boundries. Secondly, chemical dissolution of certains minerals such as quartz occurs at

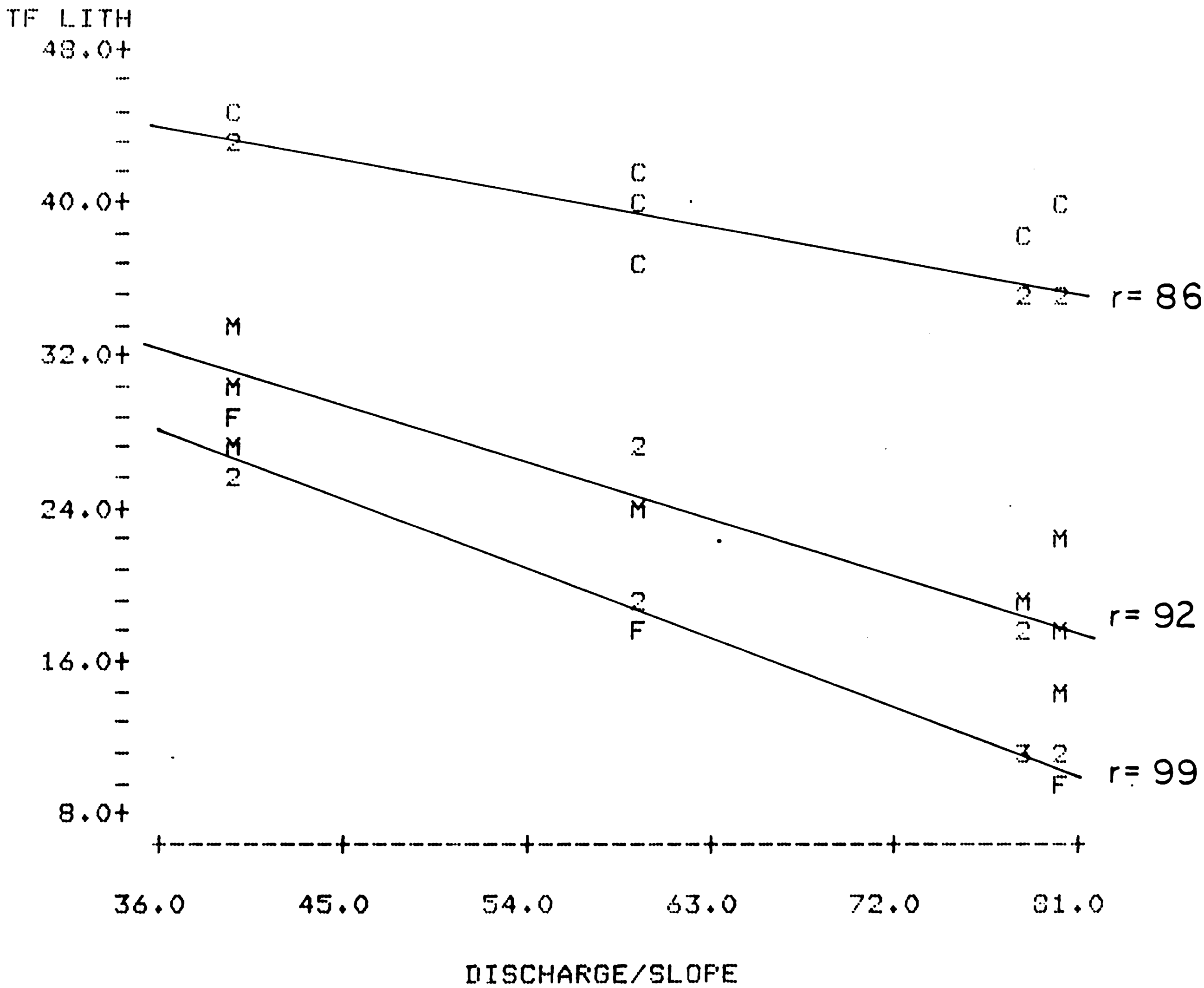


Figure 7. Percent lithic fragments versus discharge/slope for watersheds draining the Tallulah Falls Formation source rock (r=correlation coefficient for each grain size).

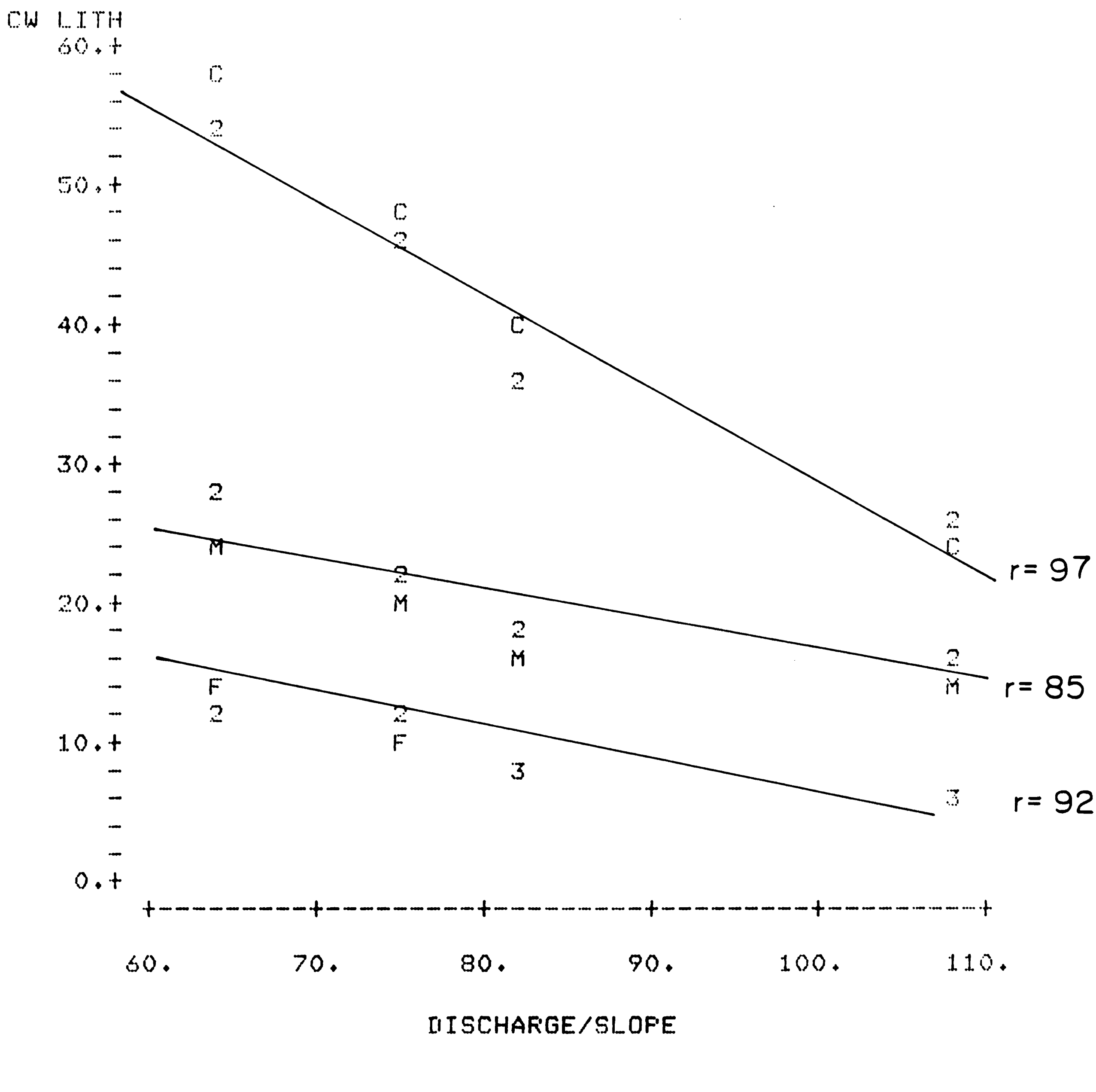


Figure 8. Percent lithic fragments versus discharge/slope for watersheds draining the Coweeta Group source rock (r=correlation coefficient for each grain size).

such a slow rate in the weathering profile that the duration of weathering may be too short to see any chemical weathering imprints on these monominerallic grains. However, the chemical destruction of one labile crystal in a polyimineral lic grain may cause a more rapid physical breakdown of that grain and thus make lithic fragments more prone to develope chemical weathering imprints while still in the source area.

The results of this new plot differ from the preliminary results of this study which found that the micas were the best indicators of climatic differentation across the Coweeta Basin. However by comparing the correlation coefficients of the lithic fragment abundance versus the total chemical weathering (Figures 7 and 8) to the mica abundance versus the discharge (Figures 9 and 10), it becomes evident that the correlation between the modal abundance of lithic fragments and the total chemical weathering is the most statistically valid (significant at the 1% level) for all three size fractions in both the Coweeta Group and Tallulah Falls Formation sediments. These results are interpreted to mean that the modal abundance of lithic fragments in the sediment is very strongly correlated with the total weathering in the source area, but that the modal abundance of mica in the sediment is correlated only with the discharge or intensity of weathering in the source area. Other good correlations exist between certain grain types and the slope, discharge,

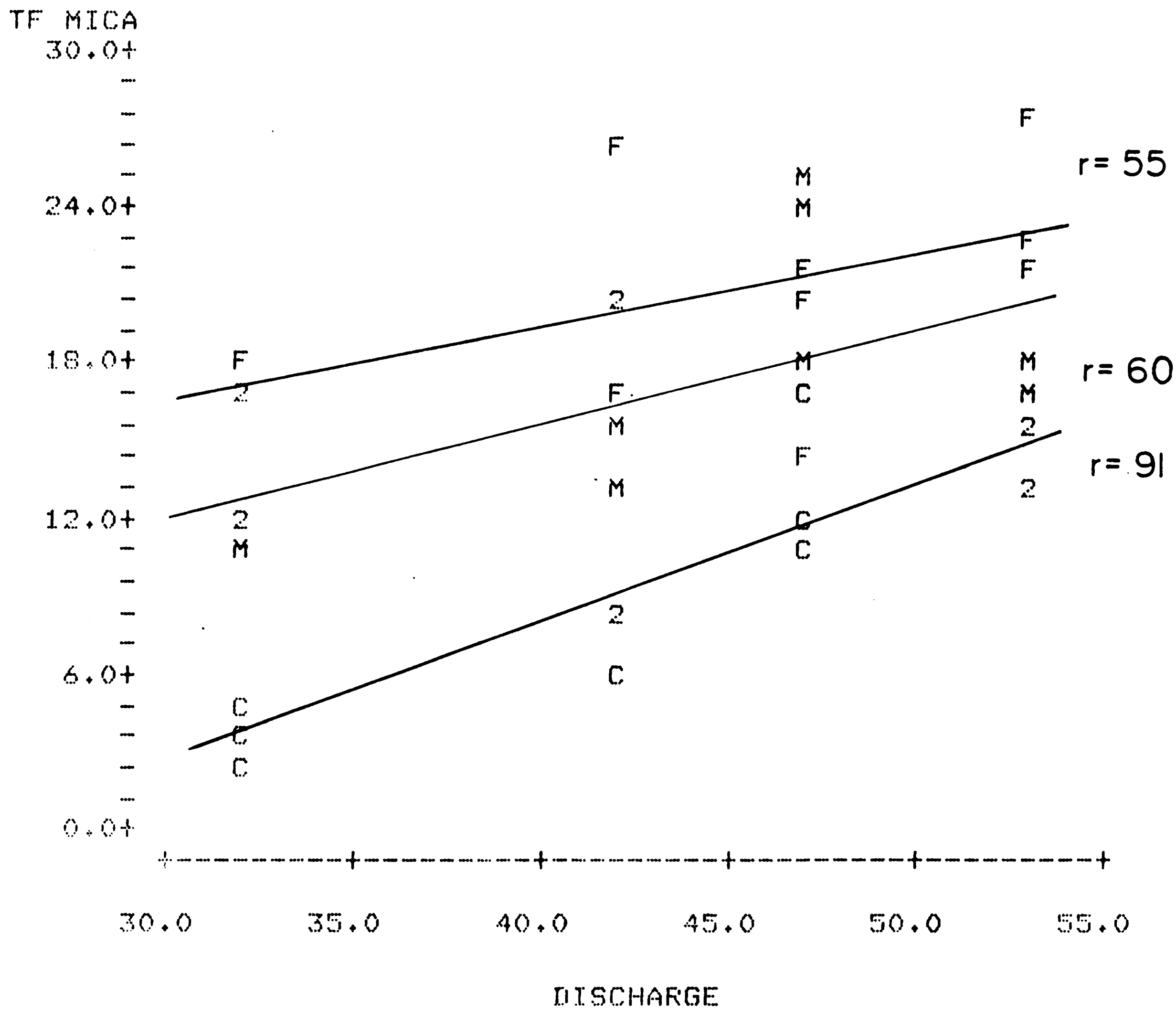


Figure 9. Percent mica versus discharge for watersheds draining the Tallulah Falls Formation source rock (r=correlation coefficient for each grain size).

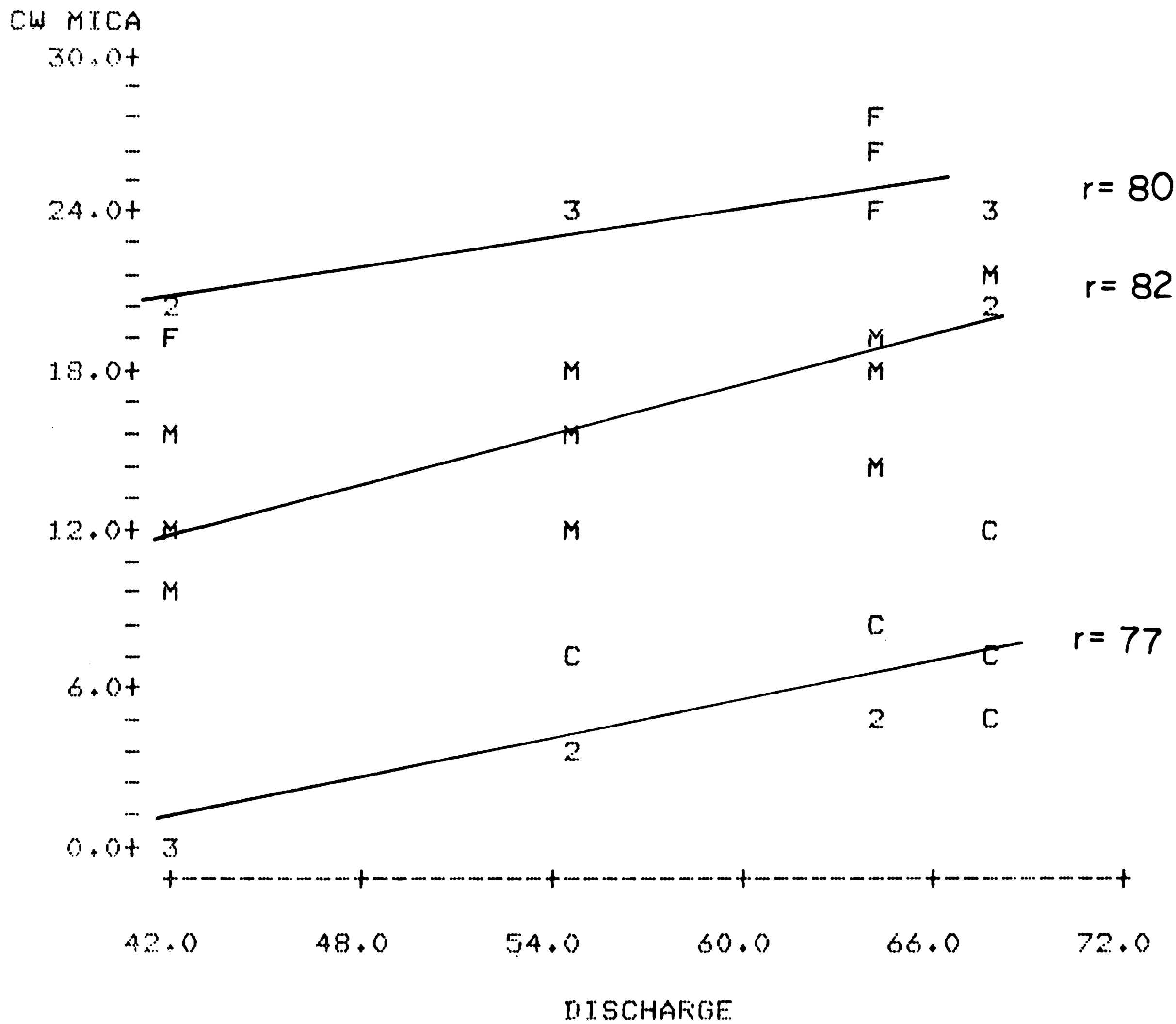


Figure 10. Percent mica versus discharge for watersheds draining the Coweeta Group source rock (r=correlation coefficient for each grain size).

or discharge/slope (see Table 6), however these correlations are either not consistant between grain sizes or not consistant between the Coweeta Group sediments and the Tallulah Falls sediments and therefore are considered much less significant.

In a very recent paper, Basu (1985) also proposes that topographic slope and climate have a combined affect upon sediments derived from a source area. He shows, using recalculated data from Ruxton (1970), that the material on the crest of hills is more highly weathered than the material on the slopes.

This study produced similar results to Basu (1985) but took a somewhat different approach. First, the duration of chemical weathering in this study area was estimated from the average topographic slope across the length of each watershed. Although the topographic slope within an individual watershed would vary greatly, this author feels that the average slope is the best estimate for predicting the duration of chemical weathering over a large area. Secondly, the intensity of chemical weathering in the Coweeta basin can best be estimated from the average discharge per unit area in an individual watershed. By combining the average discharge per unit area and slope of a watershed into the chemical weathering equation, the total chemical weathering can be determined for that watershed, and the modal abundance of lithic fragments can be predicted from the regression line for each of the three grain sizes. The reverse should also be true with the total chemical weathering of a watershed being predicted from the modal abundance of lithic fragments in the sediment.

The theory behind these results is far reaching; however, further work need be done in this field to determine if these same factors control the extent of chemical weathering in other source areas, and how this relationship might relate to ancient sediments.

SUMMARY

The abundance of lithic fragments in sand-sized sediment derived from a source area with a variable humid climate in the southern Appalachians is not correlated with climate but instead is correlated with the total extent of chemical weathering in the source area. This weathering imprint is best observed in the lithic fragment portion of the sediments, and is a function of the duration and intensity of the chemical weathering in the source area. Duration of chemical weathering is inversely related to the average topographic slope of a watershed, while intensity is directly related to the climate.

UNANSWERED QUESTIONS FOR FURTHER RESEARCH

1) Does the relationship between chemical weathering in the source area and lithic fragment abundance apply to other geographic areas?

2) What are the thresholds of this relationship?

3) Why does this relationship appear to be linear?

4) What are the ranges of sand composition that can be produced by chemical weathering alone?

5) What is the relative importance of chemical weathering in the source area to transportation for sands derived from the Coweeta basin or other source areas?

6) How is this applicable to the ancient?

APPENDIX A

Data from point counts

APPENDIX A

Data from point counts

WATERSHED 2
draining Tallulah Falls Formation bedrock

	Coarse			Medium			Fine		
Sample	2AC	2BC	2CC	2AM	2BM	2CM	2AF	2BF	2CF
Total Pts	286	297	293	365	289	290	336	307	311
Mono Qtz	33	33	37	114	98	96	156	125	131
Poly Qtz	99	106	101	83	45	53	18	13	16
Lithics	108	117	113	89	78	88	75	65	76
Mica	7	9	12	37	31	27	49	47	48
Garnet	18	17	18	5	9	2	1	1	2
Heavies	16	13	8	31	22	15	33	40	25
Plag	5	3	4	6	6	9	4	8	1
Other	-	-	-	-	-	-	-	8	12

Modal Percent of Total

Mono Qtz	11.5	11.1	12.6	31.2	33.9	33.1	46.4	40.7	42.1
Poly Qtz	34.6	35.7	34.5	22.7	15.6	18.3	5.4	4.2	5.1
Lithics	37.8	39.4	38.6	24.4	27.0	30.3	22.3	21.1	24.4
Mica	2.4	3.0	4.1	10.1	10.7	9.3	14.6	15.3	15.4
Garnet	6.2	5.7	6.1	1.4	3.1	.7	.3	.3	.6
Heavies	5.6	4.4	2.7	8.5	7.6	5.2	9.8	13.0	8.0
Plag	1.7	1.0	1.4	1.6	2.1	3.1	1.2	2.6	.3
Other	-	-	-	-	-	-	-	2.6	3.8

Modal Percent of Mono Qtz, Poly Qtz, Lithics, and Mica Recalculated to 100%

Total Pts	247	265	263	323	252	264	298	250	271
Mono Qtz	13.4	12.5	14.1	35.3	38.9	36.4	52.3	50.0	48.4
Poly Qtz	40.0	40.0	38.4	25.7	17.9	20.0	6.0	5.2	5.9
Lithics	43.7	44.1	43.0	27.7	31.0	33.4	25.2	26.0	28.0
Mica	2.8	3.4	4.6	11.5	12.3	10.3	16.4	18.8	17.7

WATERSHED 10
draining Tallulah Falls Formation bedrock

Sample	Coarse 10AC	10BC	10CC	Medium 10AM	10BM	10CM	Fine 10AF	10BF	10CF
Total Pts	318	279	312	300	264	292	288	281	297
Mono Qtz	47	54	48	108	91	106	160	147	144
Poly Qtz	101	91	117	70	63	65	14	18	16
Lithics	75	91	100	47	53	39	30	26	29
Mica	17	23	35	40	32	55	51	37	73
Garnet	18	8	6	5	2	3	3	6	2
Heavies	12	7	3	15	16	13	19	40	24
Plag	6	2	5	10	2	3	1	2	3
Other	9	3	7	5	5	8	10	5	6

Modal Percent of Total

Mono Qtz	14.8	19.4	15.0	36.0	34.5	36.3	55.5	52.3	48.5
Poly Qtz	31.8	32.6	36.4	23.3	23.9	22.3	4.9	6.4	5.4
Lithics	33.9	32.6	31.5	15.6	20.0	13.3	10.4	9.3	9.8
Mica	5.3	8.2	10.9	13.3	12.1	18.8	17.7	13.2	24.6
Garnet	5.7	2.9	1.9	1.7	.7	1.0	1.0	2.1	.6
Heavies	3.8	2.5	.9	5.0	6.1	4.4	6.6	14.2	8.1
Plag	1.9	.7	1.5	3.3	.7	1.0	.4	.7	1.0
Other	2.8	1.1	2.1	1.6	1.9	2.7	3.5	1.8	2.0

Modal Percent of Mono Qtz ,Poly Qtz, Lithics, and Mica Recalculated to 100%

Total Pts	273	259	290	265	239	265	255	228	262
Mono Qtz	17.2	20.8	16.5	40.7	38.1	40.0	62.7	64.4	55.0
Poly Qtz	37.0	35.1	40.3	26.4	26.4	24.5	5.5	7.9	6.1
Lithics	39.6	35.1	34.5	17.7	22.2	15.0	11.8	11.3	11.1
Mica	6.2	8.8	8.6	15.1	13.4	20.7	20.0	16.2	27.9

WATERSHED 34
draining Tallulah Falls Formation bedrock

Sample	Coarse			Medium			Fine		
	34AC	34BC	34CC	34AM	34BM	34CM	34AF	34BF	34CF
Total Pts	340	328	344	311	293	338	341	312	357
Mono Qtz	59	46	65	118	119	126	197	199	197
Poly Qtz	92	101	110	48	57	56	12	17	14
Lithics	111	106	95	50	54	56	33	32	37
Mica	53	37	37	74	50	78	63	43	69
Garnet	5	8	6	6	1	1	1	-	-
Heavies	16	9	5	7	7	17	33	20	38
Plag	2	7	2	6	1	1	-	-	-
Other	2	4	4	2	4	3	2	1	2

Modal Percent of Total

Mono Qtz	17.3	14.0	18.9	37.9	40.6	37.3	57.7	63.8	55.1
Poly Qtz	27.0	30.8	31.9	15.4	19.4	16.5	3.5	5.5	3.9
Lithics	32.6	35.4	33.4	16.1	18.4	16.5	9.6	10.3	10.4
Mica	15.6	11.3	10.7	23.8	17.0	23.0	18.7	13.7	19.3
Garnet	1.5	2.4	1.7	1.9	.3	.3	.3	-	-
Heavies	4.7	2.7	1.5	2.3	2.4	5.0	9.7	6.4	10.6
Plag	.6	2.1	.6	1.9	.3	.3	-	-	-
Other	.6	1.2	1.2	.6	1.4	.9	.6	.3	.6

Modal Percent of Mono Qtz, Poly Qtz, Lithics, and Mica Recalculated to 100%

Total Pts	315	300	327	290	280	316	305	291	317
Mono Qtz	18.7	15.3	19.9	40.7	42.5	39.6	64.6	68.3	62.2
Poly Qtz	29.2	33.6	33.6	16.6	20.3	17.7	3.9	5.8	4.4
Lithics	35.3	38.6	35.1	17.4	19.3	17.7	10.8	11.0	11.7
Mica	16.8	12.3	11.3	25.2	17.7	24.7	20.6	14.7	21.7

WATERSHED 41
draining Tallulah Falls Formation bedrock

	Coarse			Medium			Fine		
Sample	41AC	41BC	41CC	41AM	41BM	41CM	41AF	41BF	41CF
Total Pts	293	307	358	328	314	317	310	332	247
Mono Qtz	39	76	56	122	125	129	146	134	107
Poly Qtz	57	55	85	26	38	42	13	13	15
Lithics	91	97	118	72	69	74	55	52	37
Mica	33	36	39	48	46	43	62	78	42
Garnet	38	16	30	15	11	18	-	6	4
Heavies	19	16	22	25	18	13	30	43	35
Plag	16	11	8	18	7	14	3	3	2
Other	-	-	-	-	-	-	1	3	5

Modal Percent of Total

Mono Qtz	13.3	24.8	15.6	37.2	39.8	40.7	47.1	40.4	43.3
Poly Qtz	19.4	17.9	23.7	7.9	12.1	8.2	4.2	3.9	6.0
Lithics	31.1	31.6	33.0	22.5	22.0	23.3	17.7	15.6	15.0
Mica	11.3	11.7	10.9	14.6	14.6	13.6	20.0	23.5	17.0
Garnet	13.0	5.2	8.4	4.6	3.5	5.6	-	1.8	1.6
Heavies	6.5	5.2	6.1	7.6	5.7	4.1	9.7	13.0	14.2
Plag	5.4	3.6	2.2	5.5	2.2	4.4	1.0	.9	.8
Other	-	-	-	-	-	-	.3	.9	2.0

Modal Percent of Mono Qtz, Poly Qtz, Lithics, and Mica Recalculated to 100%

Total Pts	220	264	298	270	278	272	276	277	201
Mono Qtz	17.7	28.8	18.8	45.2	45.0	47.4	52.9	48.3	53.2
Poly Qtz	25.9	20.8	28.5	9.6	13.7	9.6	4.7	4.7	7.4
Lithics	41.3	36.7	39.5	27.3	24.8	27.1	19.8	18.8	18.3
Mica	13.0	13.6	13.1	17.9	16.5	16.0	22.5	28.1	21.0

WATERSHED 13
draining Coweeta Group bedrock

Sample	Coarse 13AC	13BC	13CC	Medium 13AM	13BM	13CM	Fine 13AF	13BF	13CF
Total Pts	318	340	359	283	270	282	300	285	320
Mono Qtz	98	86	96	147	147	147	162	163	163
Poly Qtz	62	72	80	28	25	22	12	8	11
Lithics	130	154	151	51	53	56	32	30	27
Mica	2	2	3	30	23	40	51	51	52
Garnet	10	7	15	2	-	-	2	-	-
Heavies	9	12	9	16	13	14	34	31	58
Plag	1	1	2	3	1	1	1	1	-
Other	6	6	3	6	8	2	6	1	9

Modal Percent of Total

Mono Qtz	30.8	25.3	26.7	51.9	54.4	52.1	54.0	57.2	51.0
Poly Qtz	19.5	21.2	22.3	9.9	9.2	7.8	4.0	2.8	3.4
Lithics	40.9	45.3	42.1	18.0	19.6	19.8	10.6	10.5	8.4
Mica	.6	.6	.8	10.6	8.5	14.2	17.0	17.9	16.3
Garnet	3.1	2.1	4.2	.7	-	-	.7	-	-
Heavies	2.8	3.5	2.5	5.7	4.8	5.0	11.3	10.9	18.1
Plag	.3	.3	.6	1.1	.4	.4	.3	.4	-
Other	1.9	1.8	.8	2.2	3.0	.7	2.0	.3	2.8

Modal Percent of Mono Qtz, Poly Qtz, Lithics, and Mica Recalculated to 100%

Total Pts	292	314	330	256	248	265	257	252	253
Mono Qtz	33.6	27.4	29.1	57.4	59.3	55.5	63.0	64.7	64.4
Poly Qtz	21.2	22.9	24.2	10.9	10.1	8.3	4.7	3.2	4.3
Lithics	44.5	49.0	45.8	19.9	21.4	21.1	12.5	11.9	10.7
Mica	.7	.7	.9	11.7	9.3	15.1	19.8	20.2	20.5

WATERSHED 27
draining Coweeta Group bedrock

	Coarse			Medium			Fine		
Sample	27AC	27BC	27CC	27AM	27BM	27CM	27AF	27BF	27CF
Total Pts	296	307	248	300	315	290	284	271	276
Mono Qtz	65	58	43	138	137	132	167	160	160
Poly Qtz	91	80	90	28	44	27	7	4	7
Lithics	97	112	81	48	49	45	22	19	20
Mica	11	36	16	58	59	53	61	59	60
Garnet	10	4	2	3	1	2	-	-	1
Heavies	6	7	1	15	7	8	20	22	20
Plag	16	9	9	6	15	20	6	4	4
Other	-	1	4	4	3	3	1	3	4

Modal Percent of Total

Mono Qtz	22.0	19.0	17.3	46.0	43.5	46.5	58.8	59.0	58.0
Poly Qtz	30.7	26.0	36.3	9.3	14.0	9.3	2.5	1.5	2.5
Lithics	32.7	36.6	32.6	16.0	15.5	15.5	7.7	7.0	7.2
Mica	7.7	3.7	11.7	19.3	18.7	18.2	21.5	21.8	21.7
Garnet	3.4	1.3	.8	1.0	.3	.7	-	-	.4
Heavies	2.0	2.3	.4	5.0	2.2	2.8	7.0	8.1	7.2
Plag	5.4	2.9	3.6	2.0	4.8	6.9	2.1	1.5	1.4
Other	-	.3	1.6	1.3	1.0	1.0	.3	1.1	1.4

Modal Percent of Mono Qtz, Poly Qtz, Lithics, and Mica Recalculated to 100%

Total Pts	264	286	230	272	289	257	257	242	247
Mono Qtz	24.6	20.3	18.7	50.7	47.4	51.3	65.0	66.0	64.8
Poly Qtz	34.5	28.0	39.1	10.3	15.2	10.5	2.7	1.7	2.8
Lithics	36.7	39.2	35.2	17.6	16.9	17.5	8.6	7.9	8.1
Mica	4.2	12.5	7.0	21.3	20.4	20.6	23.7	24.4	24.3

WATERSHED 32
draining Coweeta Group bedrock

Sample	Coarse 32AC	32BC	32CC	Medium 32AM	32BM	32CM	Fine 32AF	32BF	32CF
Total Pts	312	250	247	283	291	287	278	299	304
Mono Qtz	117	94	100	145	156	168	181	184	180
Poly Qtz	90	73	64	24	25	31	7	10	10
Mica	9	8	17	47	41	34	63	66	65
Garnet	10	5	5	2	3	3	1	2	1
Heavies	8	6	3	18	8	5	7	18	31
Plag	1	1	2	2	3	3	1	2	1
Other	1	-	-	2	12	-	-	1	-

Modal Percent of Total

Mono Qtz	37.5	37.6	40.5	51.2	53.6	58.5	65.6	61.5	59.2
Poly Qtz	28.8	29.2	25.9	8.5	8.6	10.8	2.5	3.3	3.3
Lithics	24.3	25.2	22.7	15.1	15.5	12.5	6.1	6.0	5.6
Mica	3.1	3.3	7.1	18.1	15.4	12.0	23.5	23.7	23.9
Garnet	3.2	2.0	2.0	.7	.3	3.5	-	-	-
Heavies	2.6	2.4	1.2	6.4	2.7	1.7	2.5	6.0	10.2
Plag	.3	.4	.8	.7	1.0	1.0	.3	.7	.3
Other	.3	-	-	.7	4.1	-	-	.3	-

Modal Percent of Mono Qtz, Poly Qtz, Lithics, and Mica Recalculated to 100%

Total Pts	292	238	237	259	267	269	268	278	272
Mono Qtz	40.1	39.5	42.2	56.0	58.4	62.4	67.5	66.2	66.2
Poly Qtz	30.9	30.7	27.0	9.3	9.4	11.5	2.6	3.6	3.7
Lithics	26.0	26.5	23.6	16.6	16.9	13.4	6.3	6.5	6.3
Mica	3.1	3.3	7.1	18.1	15.4	12.0	23.5	23.7	23.9

WATERSHED 37
draining Coweeta Group bedrock

Sample	Coarse 37AC	37BC	37CC	Medium 37AM	37BM	37CM	Fine 37AF	37BF	37CF
Total Pts	398	346	364	315	315	318	303	336	315
Mono Qtz	62	43	43	130	124	120	154	158	156
Poly Qtz	84	58	90	26	38	38	11	17	11
Lithics	197	177	167	76	79	80	34	37	36
Mica	19	29	15	56	41	57	79	77	65
Garnet	12	7	29	7	4	7	-	2	2
Heavies	6	10	4	3	10	15	17	27	28
Plag	16	21	15	14	16	12	4	17	13
Other	2	1	1	3	3	1	4	1	4

Modal Percent of Total

Mono Qtz	15.5	12.4	11.8	41.3	39.4	37.7	50.8	47.0	49.5
Poly Qtz	21.1	16.8	24.7	8.2	12.1	11.9	3.6	5.1	3.5
Lithics	49.4	51.0	45.9	24.1	25.1	25.2	11.2	11.0	11.4
Mica	5.2	9.4	4.7	19.4	14.5	19.3	28.4	26.6	24.2
Garnet	3.0	2.0	8.0	2.2	1.3	2.2	-	.6	.6
Heavies	1.5	2.9	1.1	1.0	3.2	4.7	5.6	8.0	8.9
Plag	4.0	6.1	4.1	4.4	5.1	3.8	1.3	5.1	4.1
Other	.5	.2	.3	1.0	1.0	.3	1.3	.3	1.3

Modal Percent of Mono Qtz, Poly Qtz, Lithics, and Mica Recalculated to 100%

Total Pts	362	307	315	288	282	295	278	289	268
Mono Qtz	17.1	14.0	13.7	45.1	44.0	40.7	55.4	54.7	58.2
Poly Qtz	23.2	18.9	28.6	9.0	13.4	12.9	4.0	5.9	4.1
Lithics	54.4	57.7	53.0	26.4	28.0	27.1	12.2	12.8	13.4
Mica	5.2	9.4	4.7	19.4	14.5	19.3	28.4	26.6	24.2

APPENDIX B

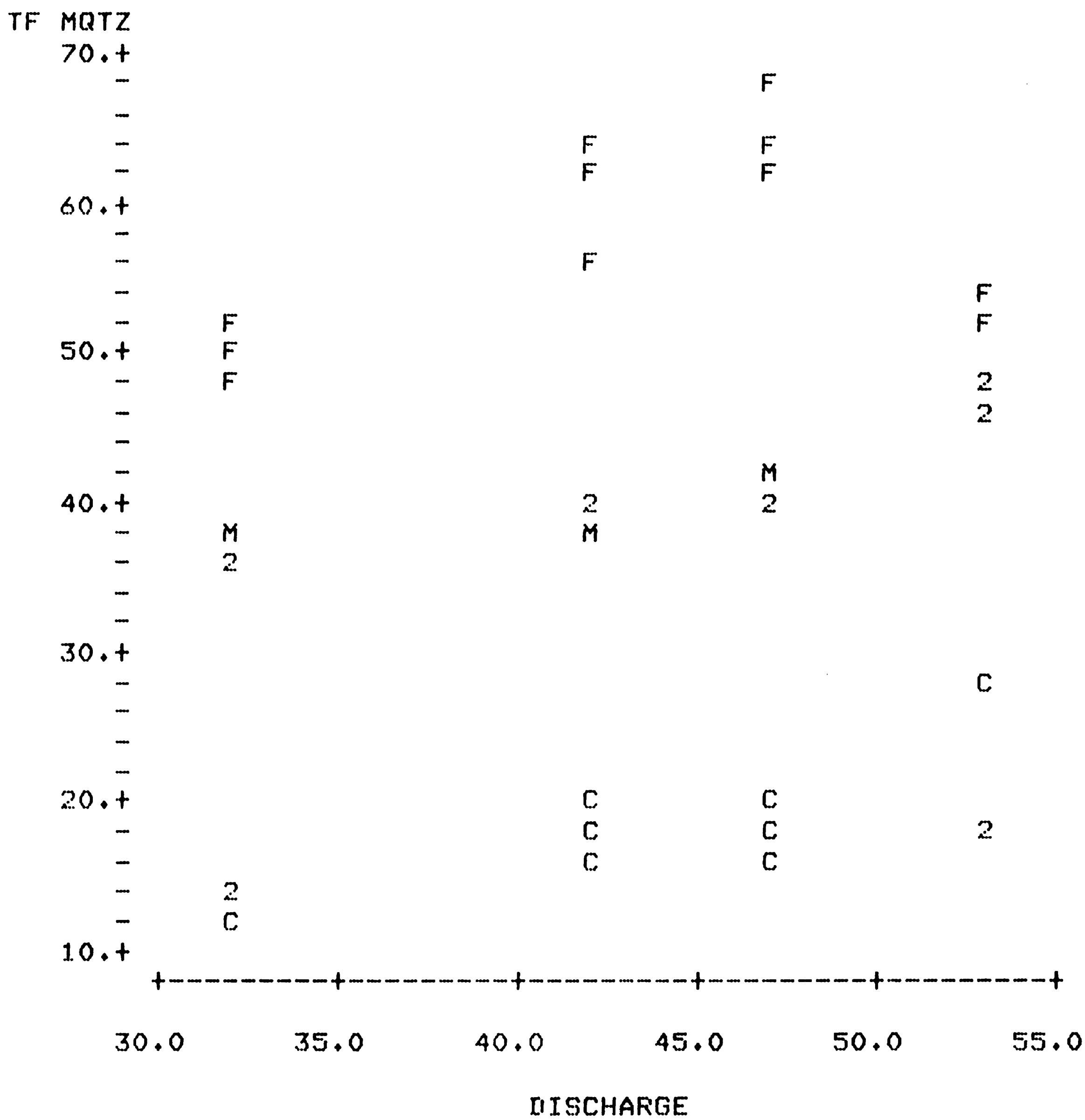
Plots of grain type abundance versus discharge, slope, and discharge/slope

APPENDIX B

Plots of grain type abundance versus discharge, slope, and discharge/slope

Abbreviation used in Appendix B:

CW = sediments derived from the Coweeta Group source rock
TF = sediments derived from the Tallulah Falls Formation source rock
MQTZ = % monocrystalline quartz
PQTZ = % polycrystalline quartz
MICA = % mica
LITH = % lithic fragment
C = coarse fraction
M = medium fraction
F = fine fraction
2 - Designates where two samples lie on or near the same point.
3 - Designates where three samples lie on or near the same point.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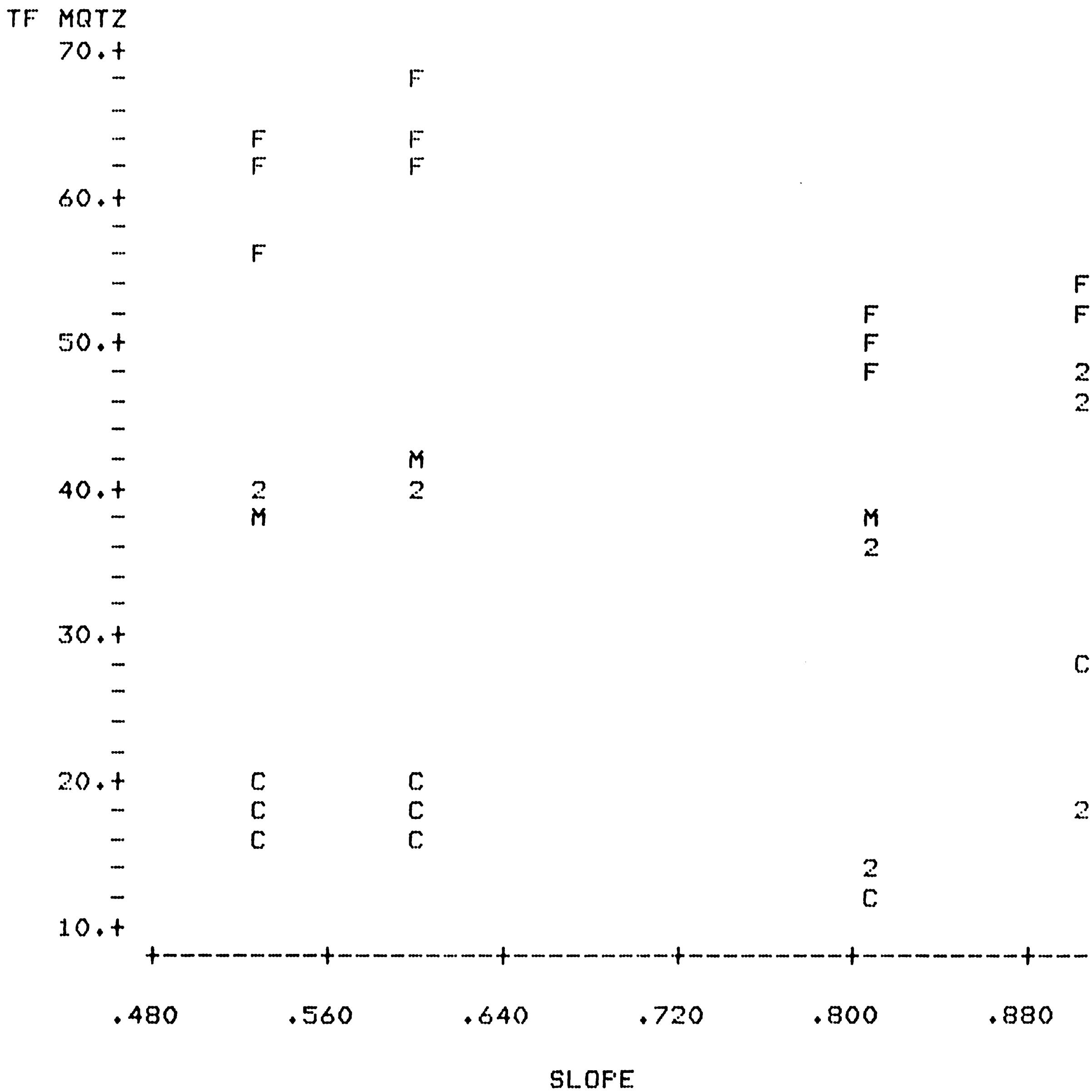
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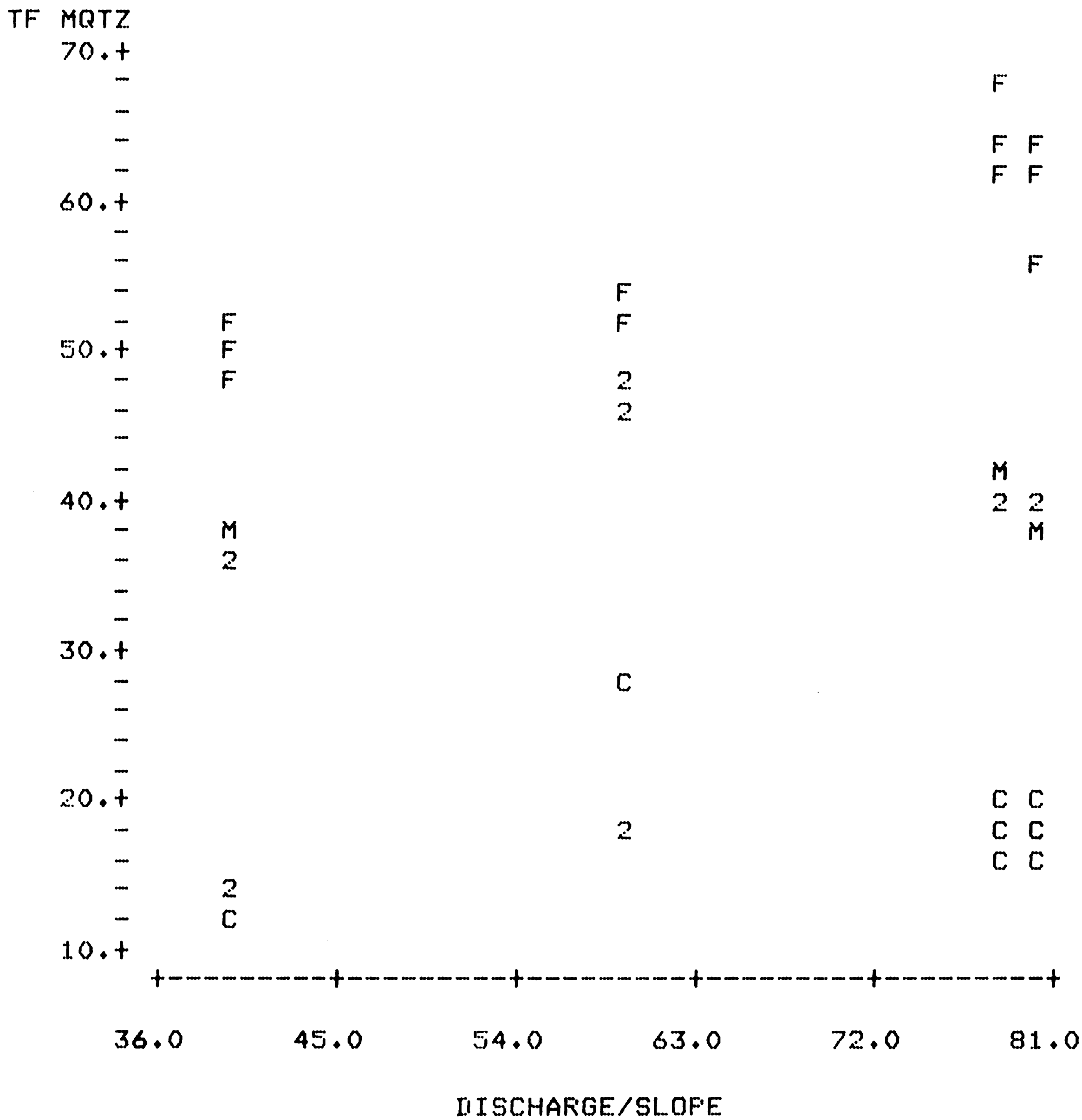
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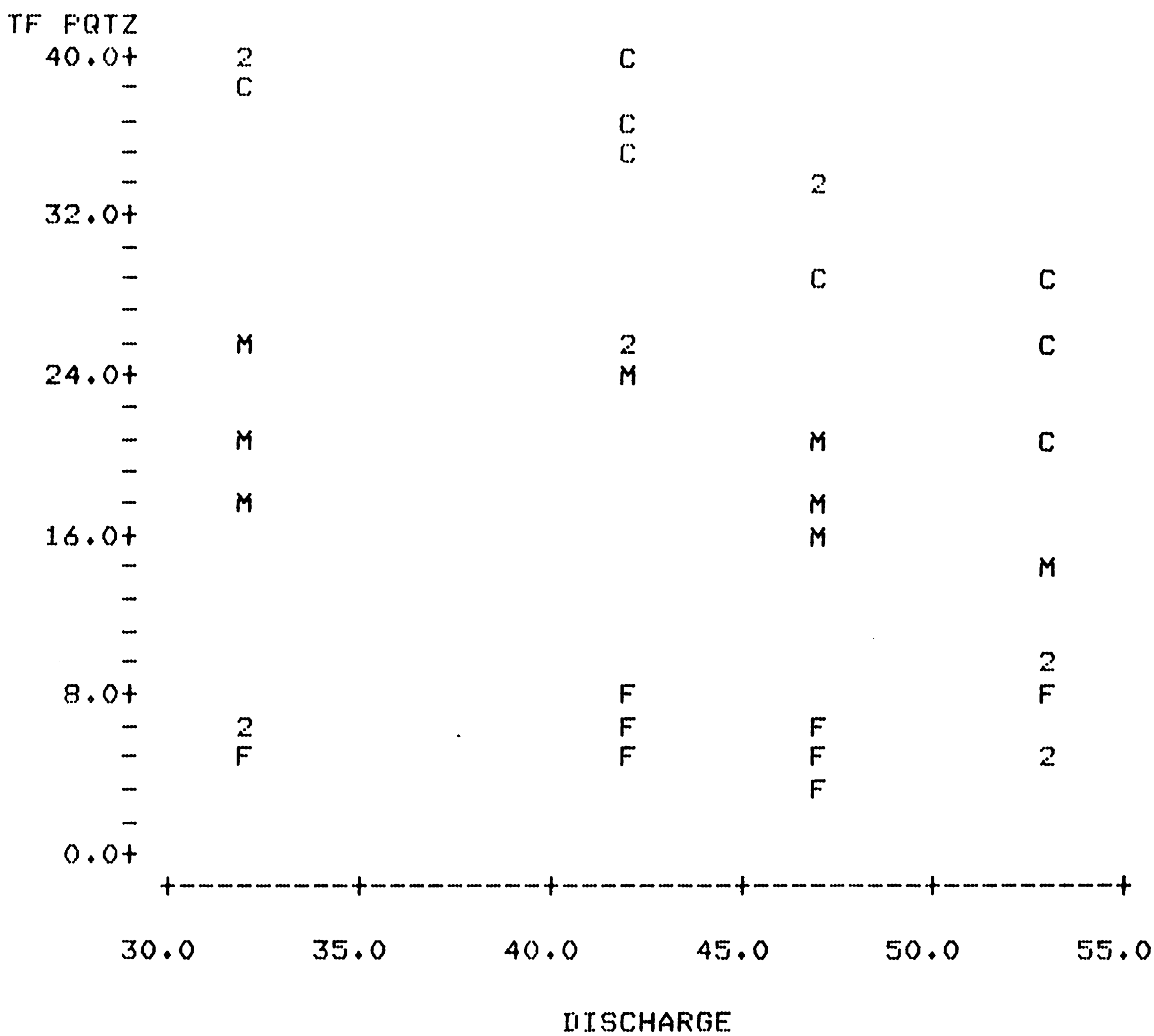
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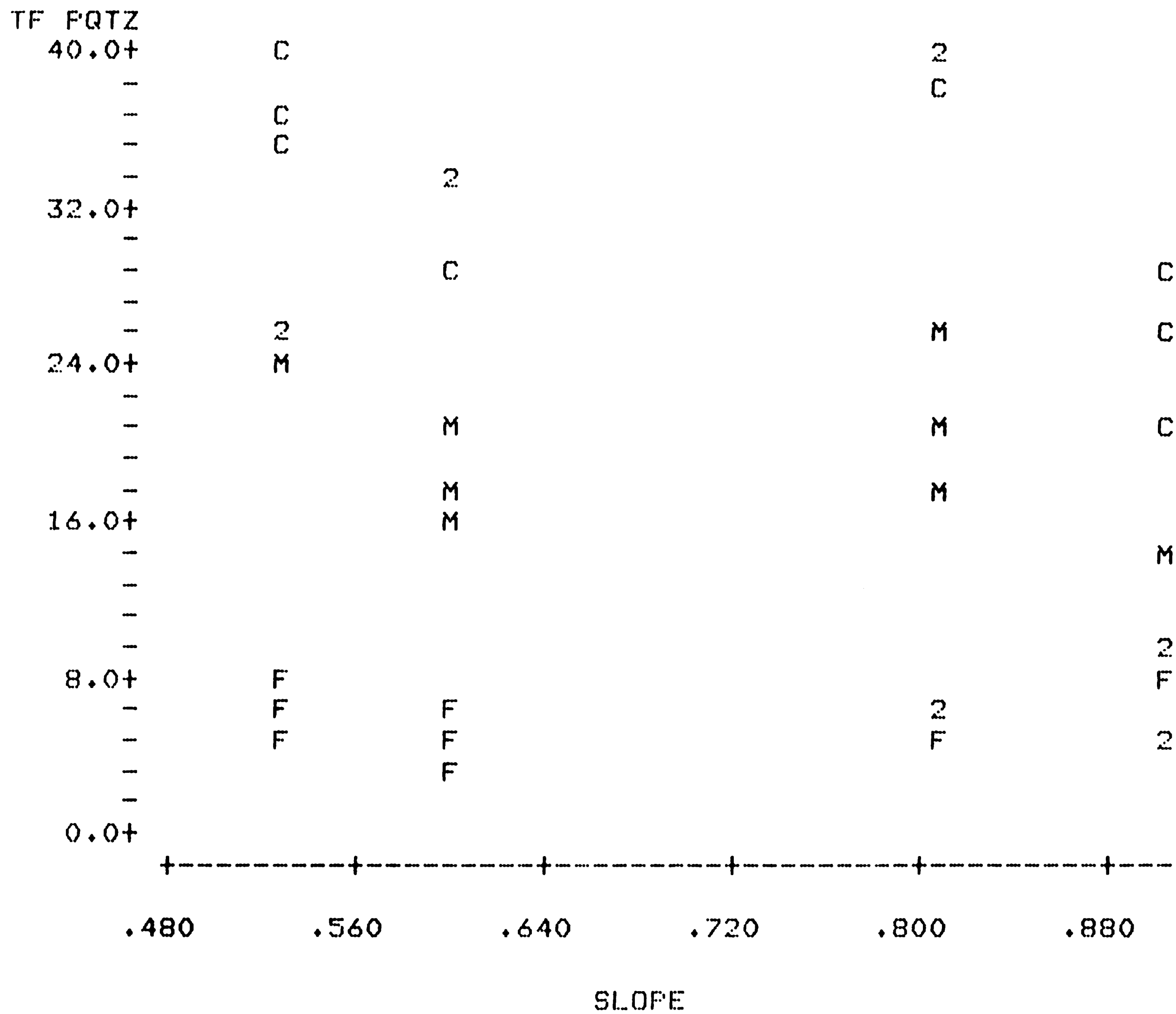
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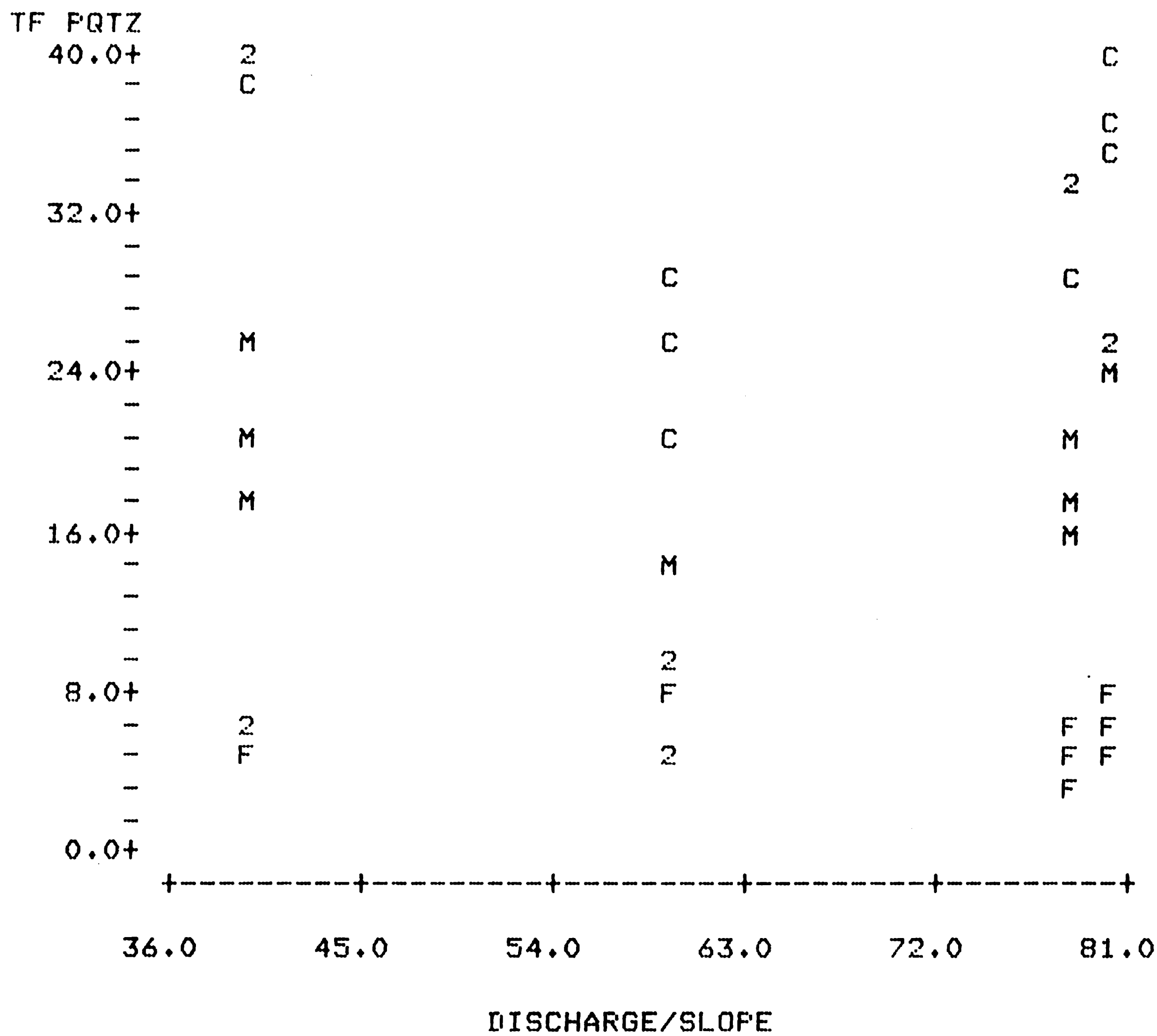
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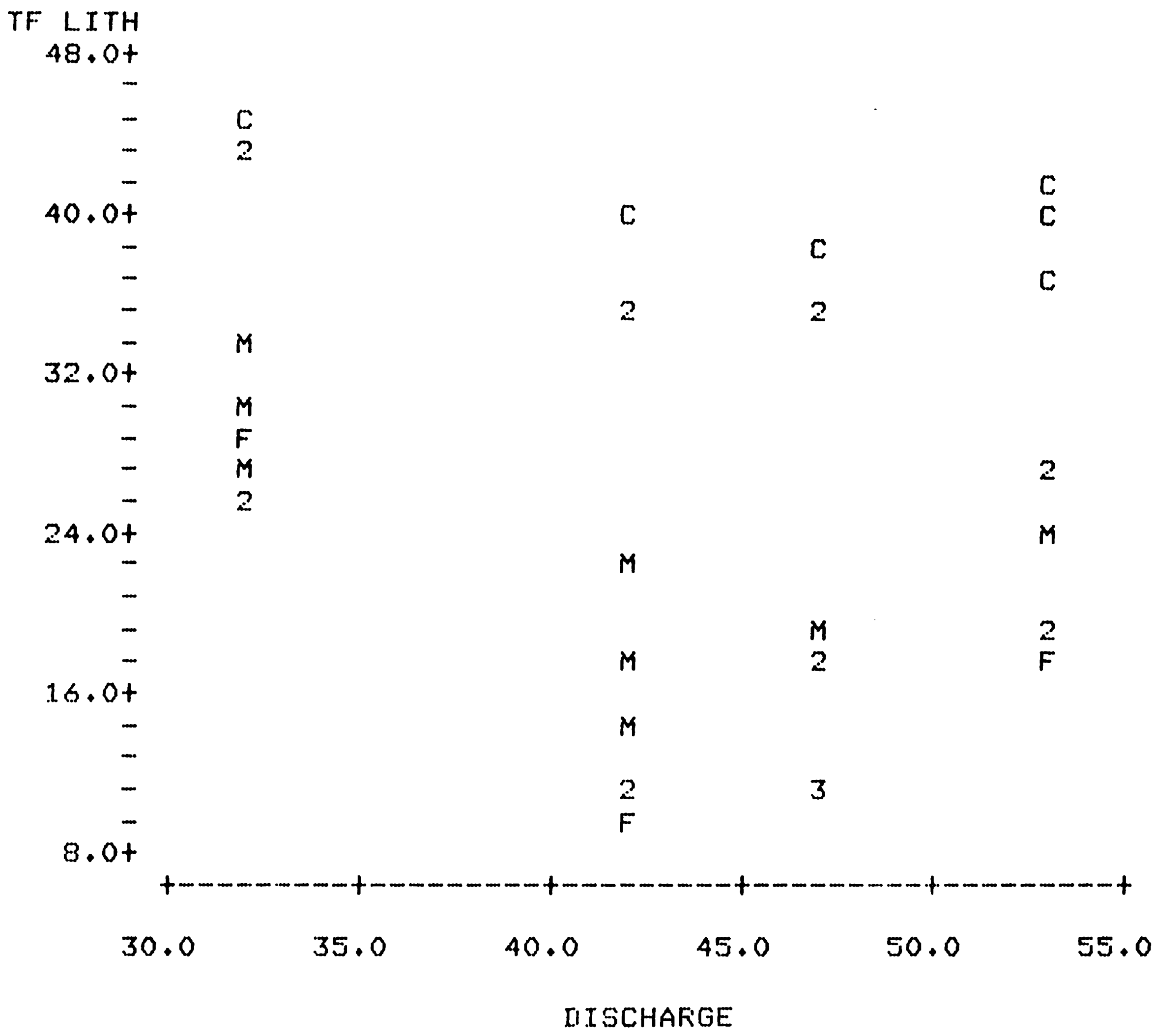
DISCHARGE/SLOPE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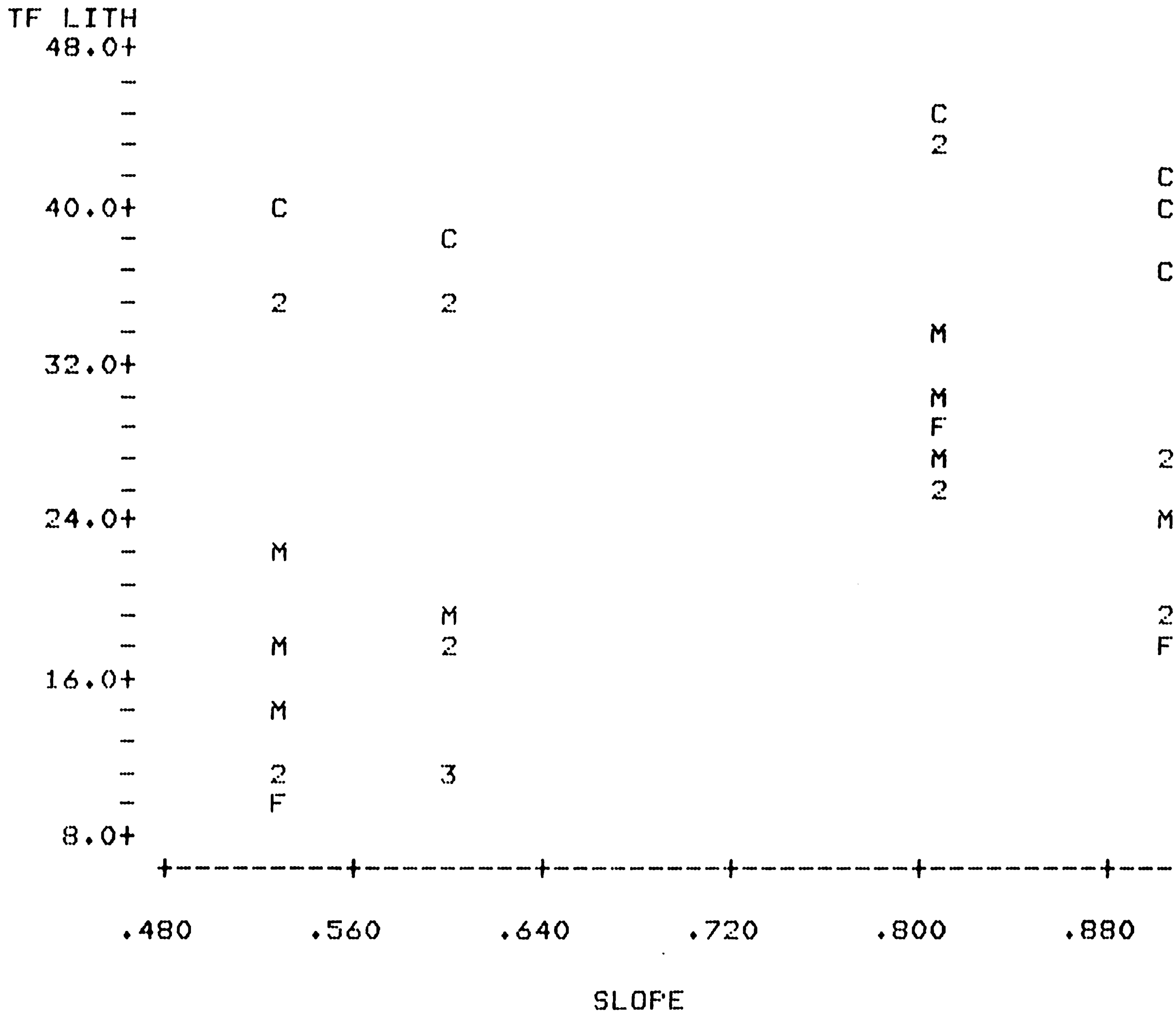
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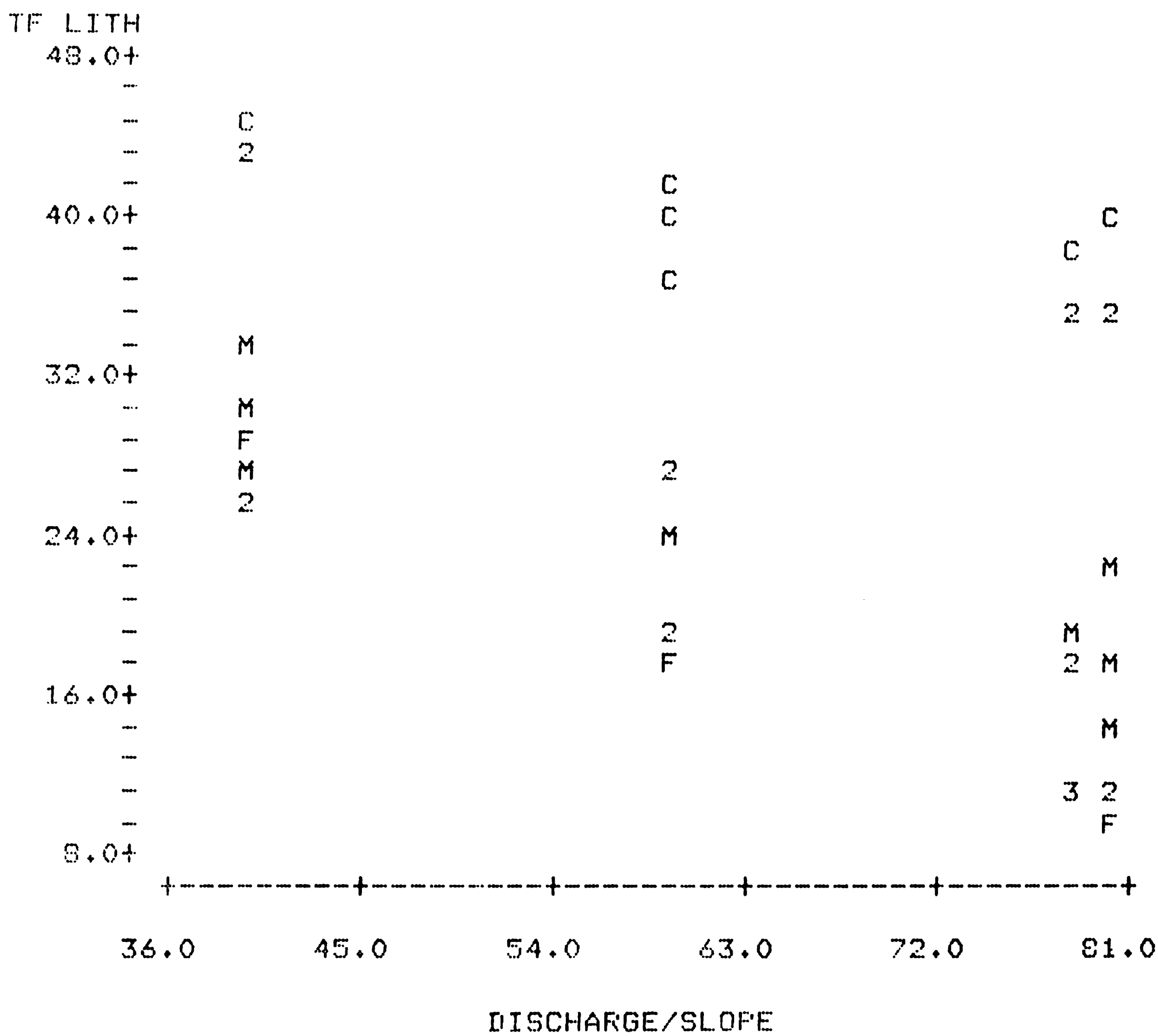
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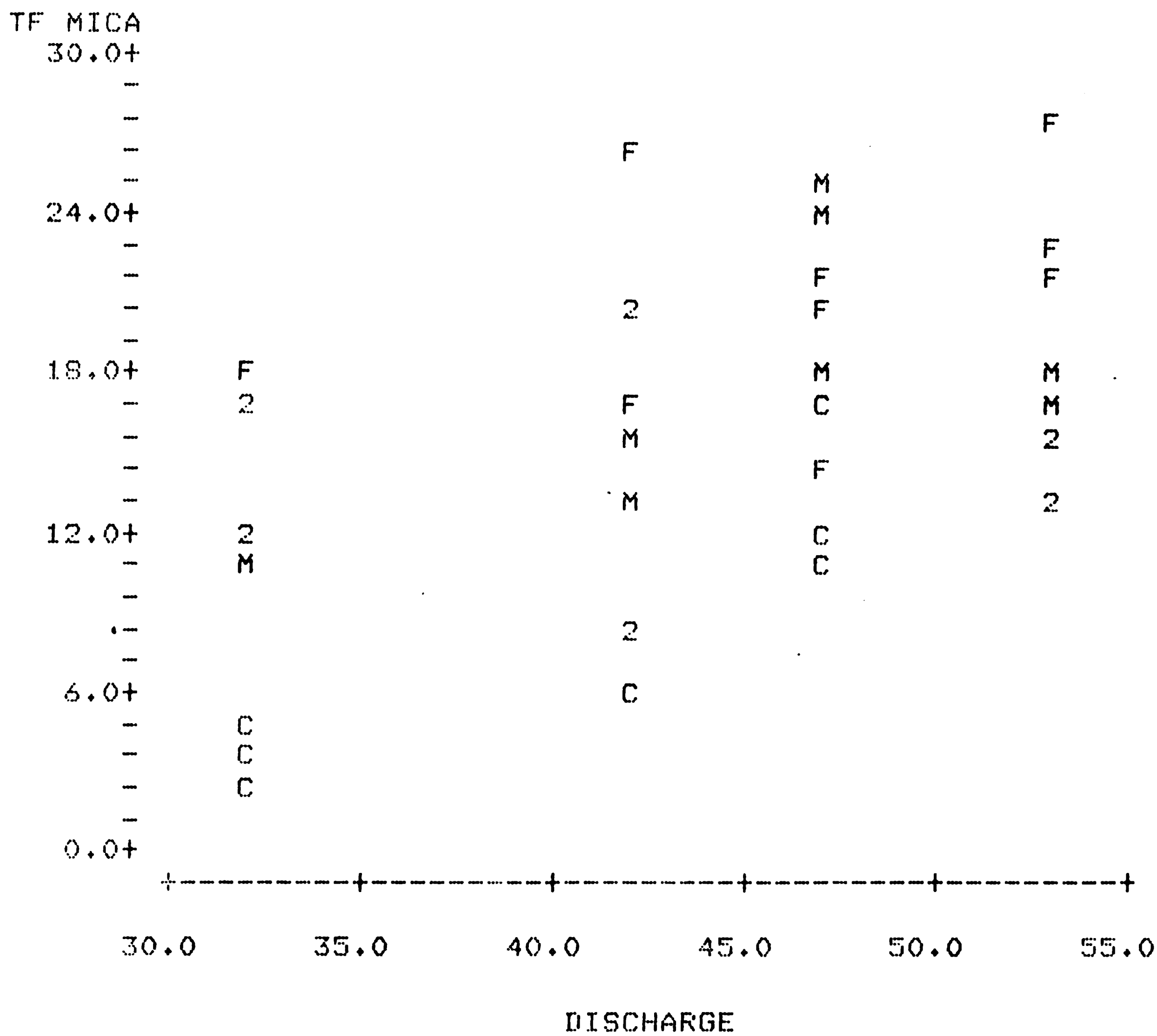
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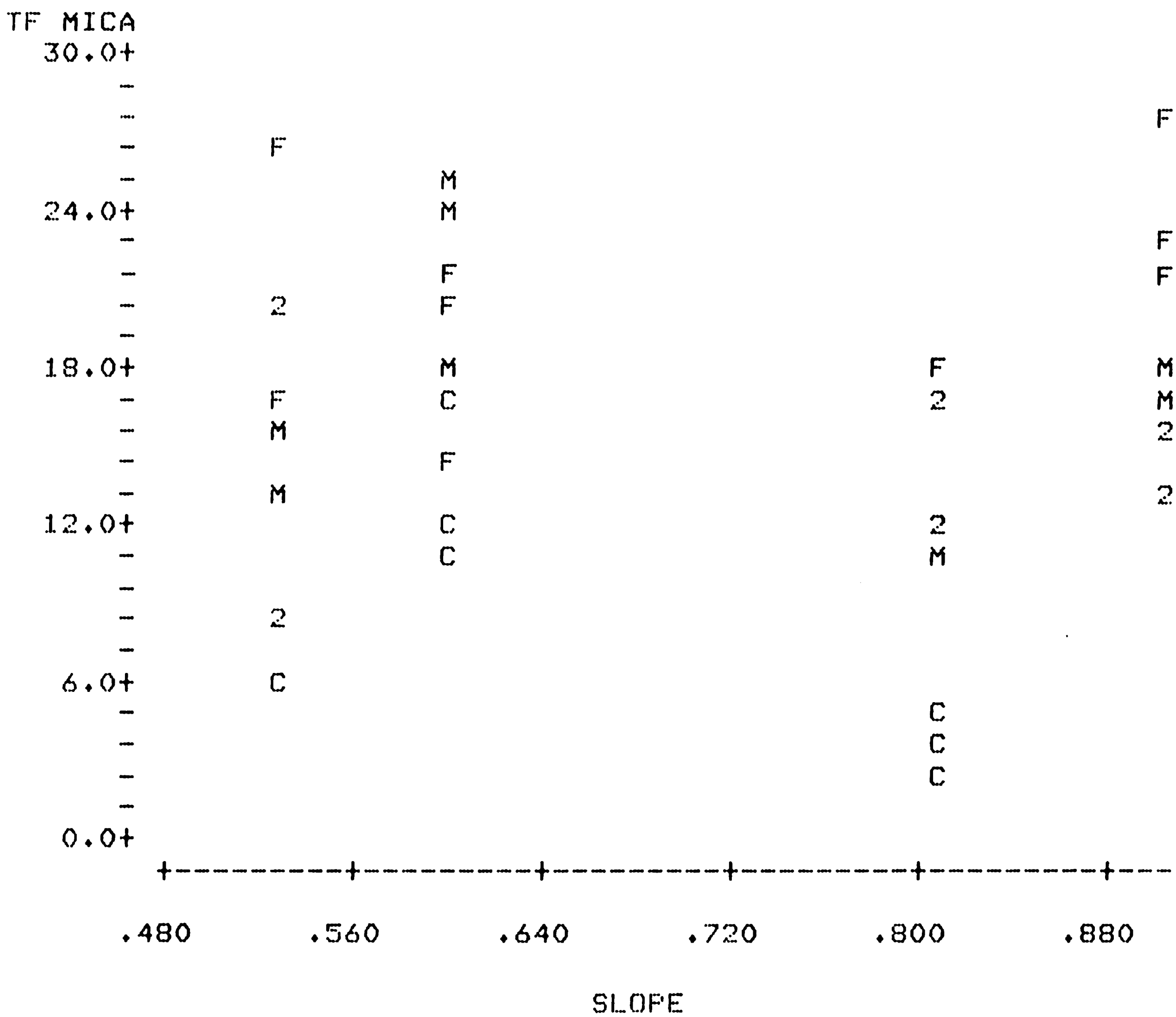
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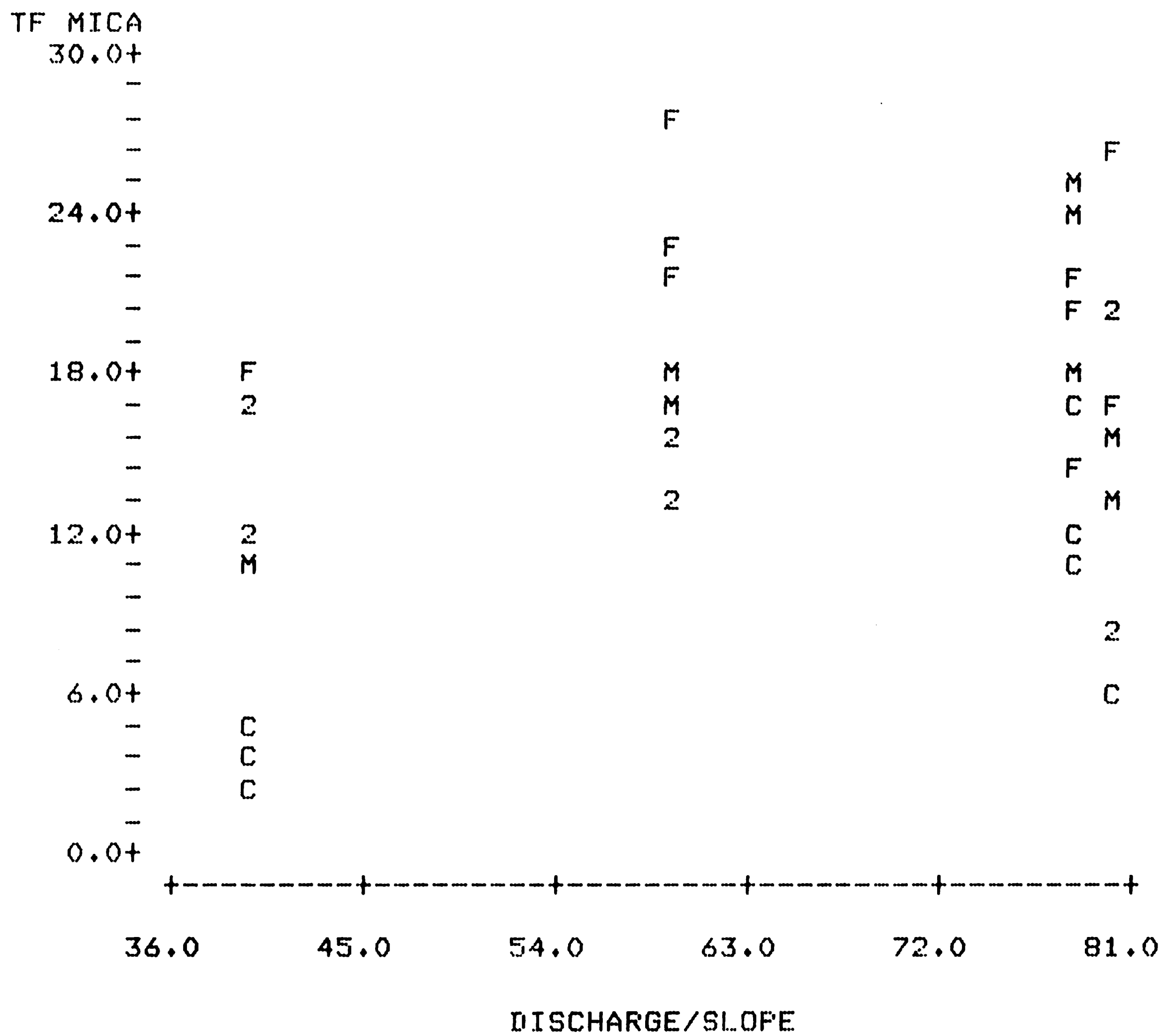
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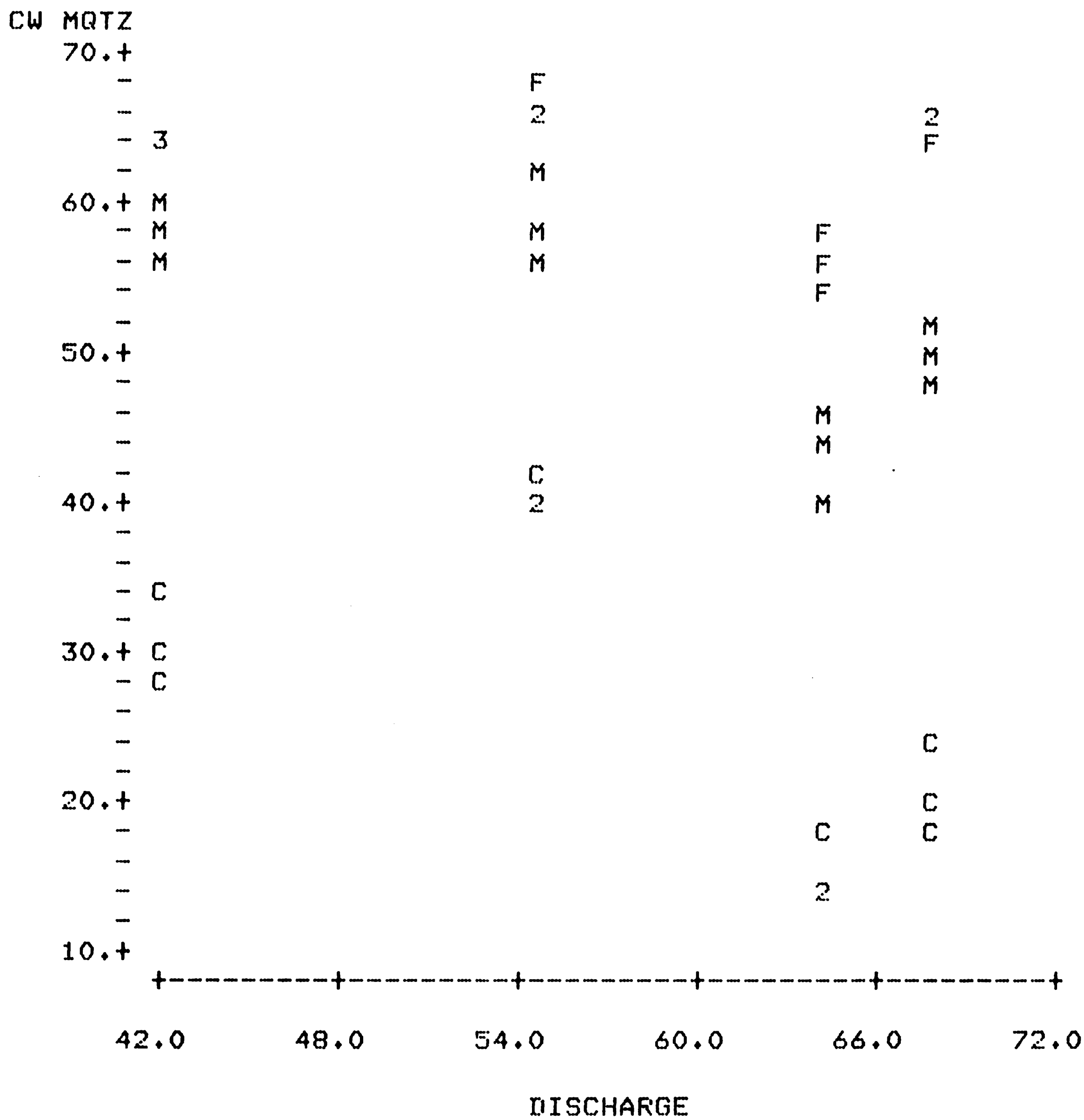
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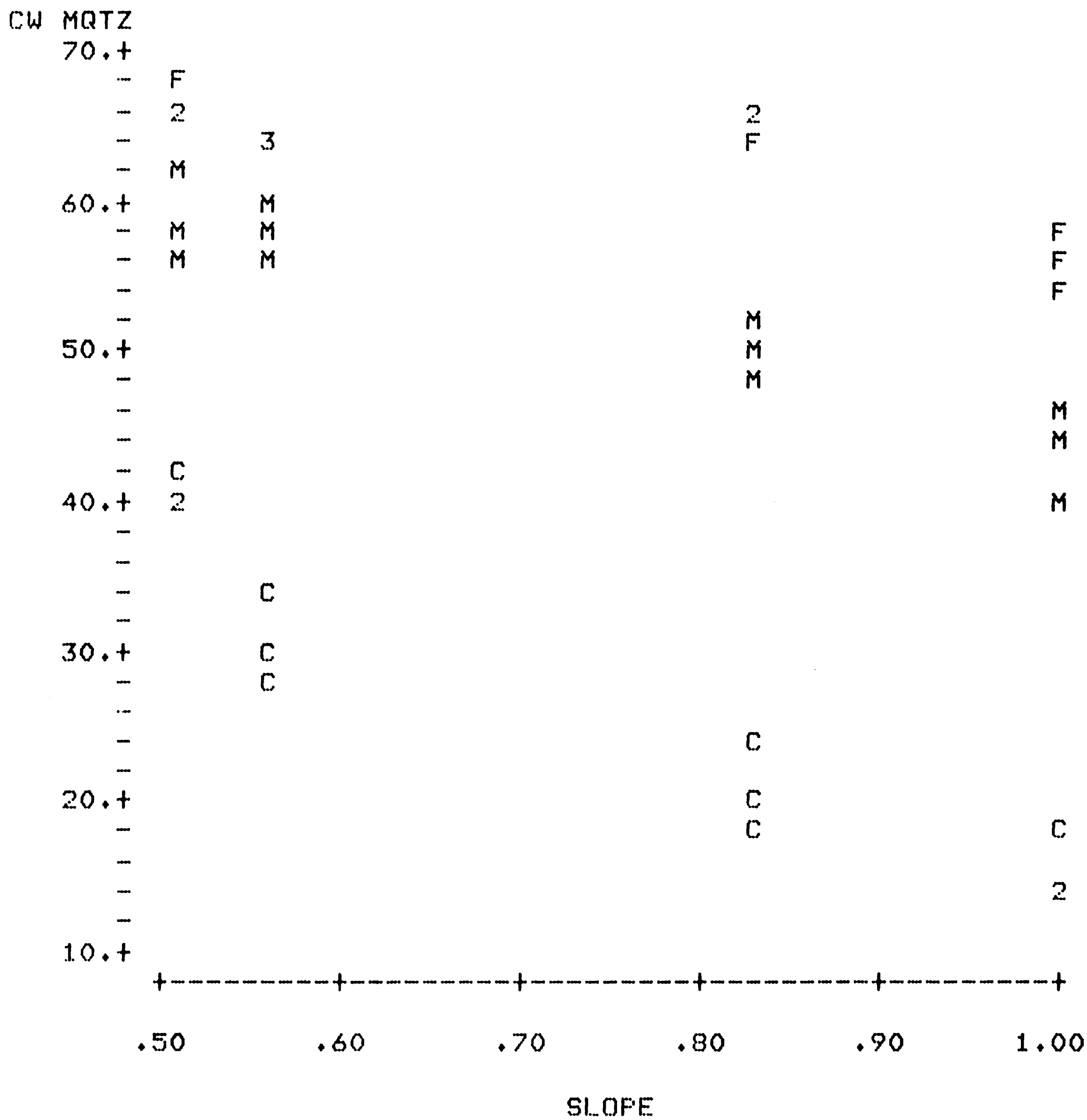
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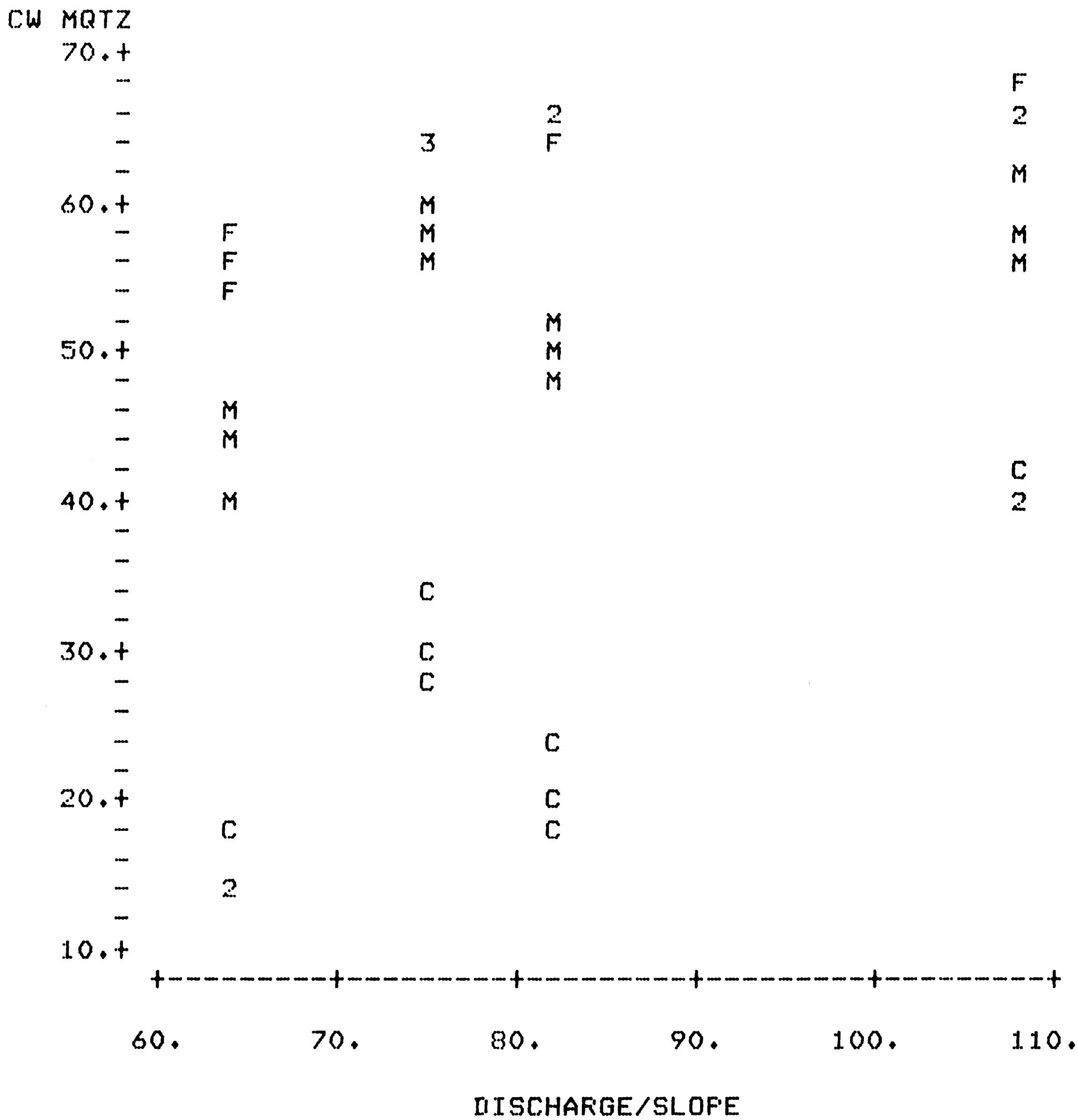
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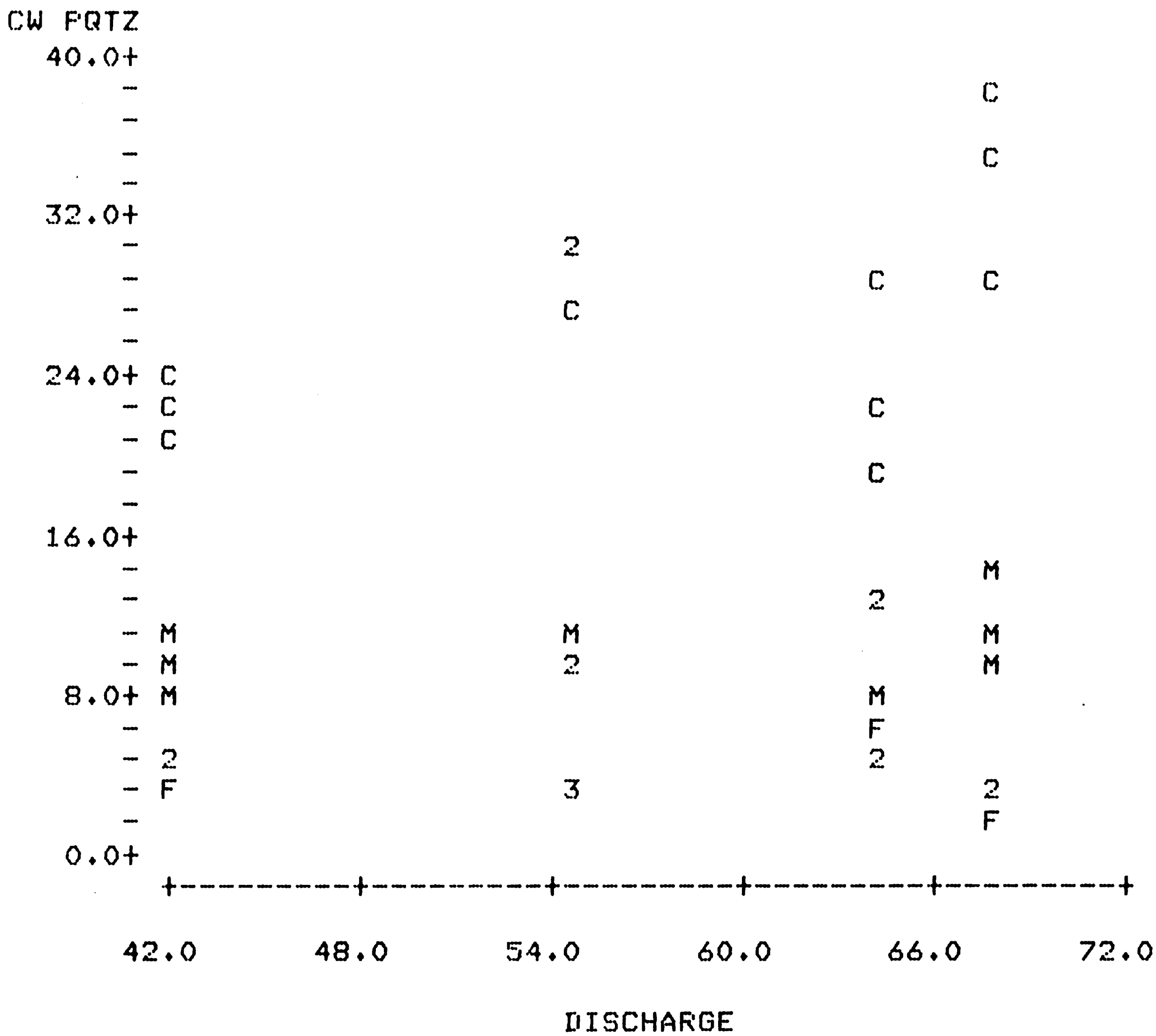
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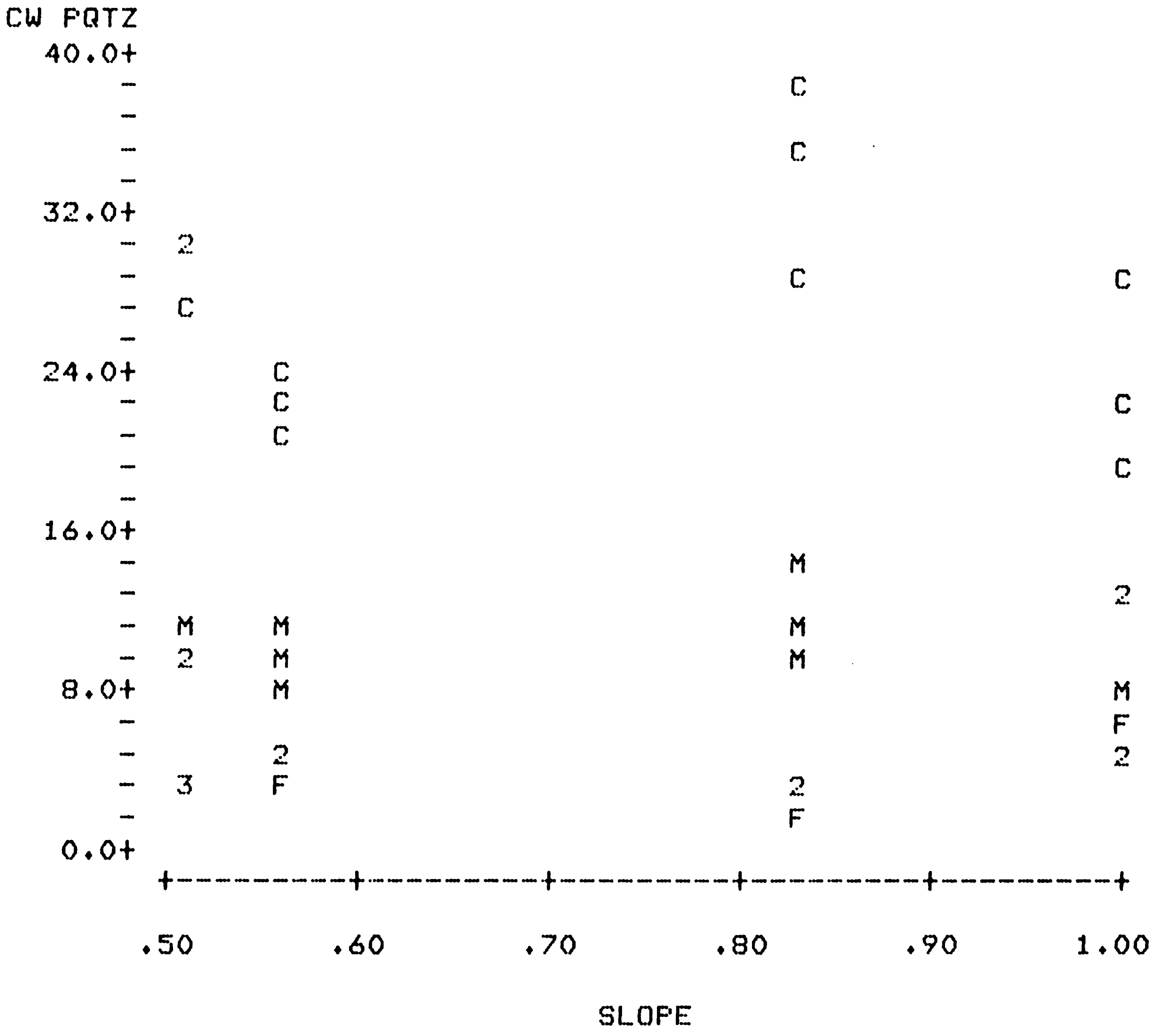
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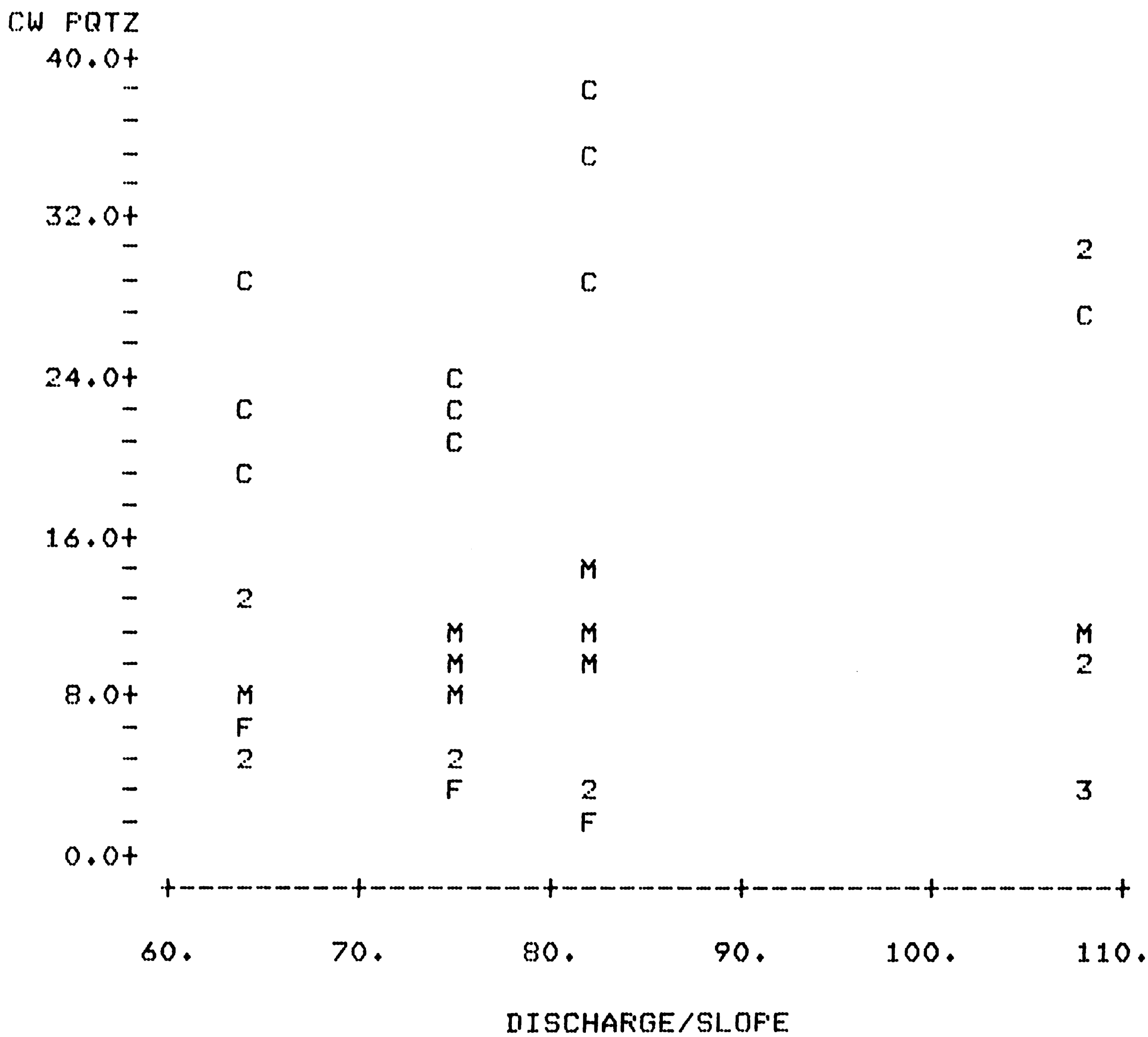
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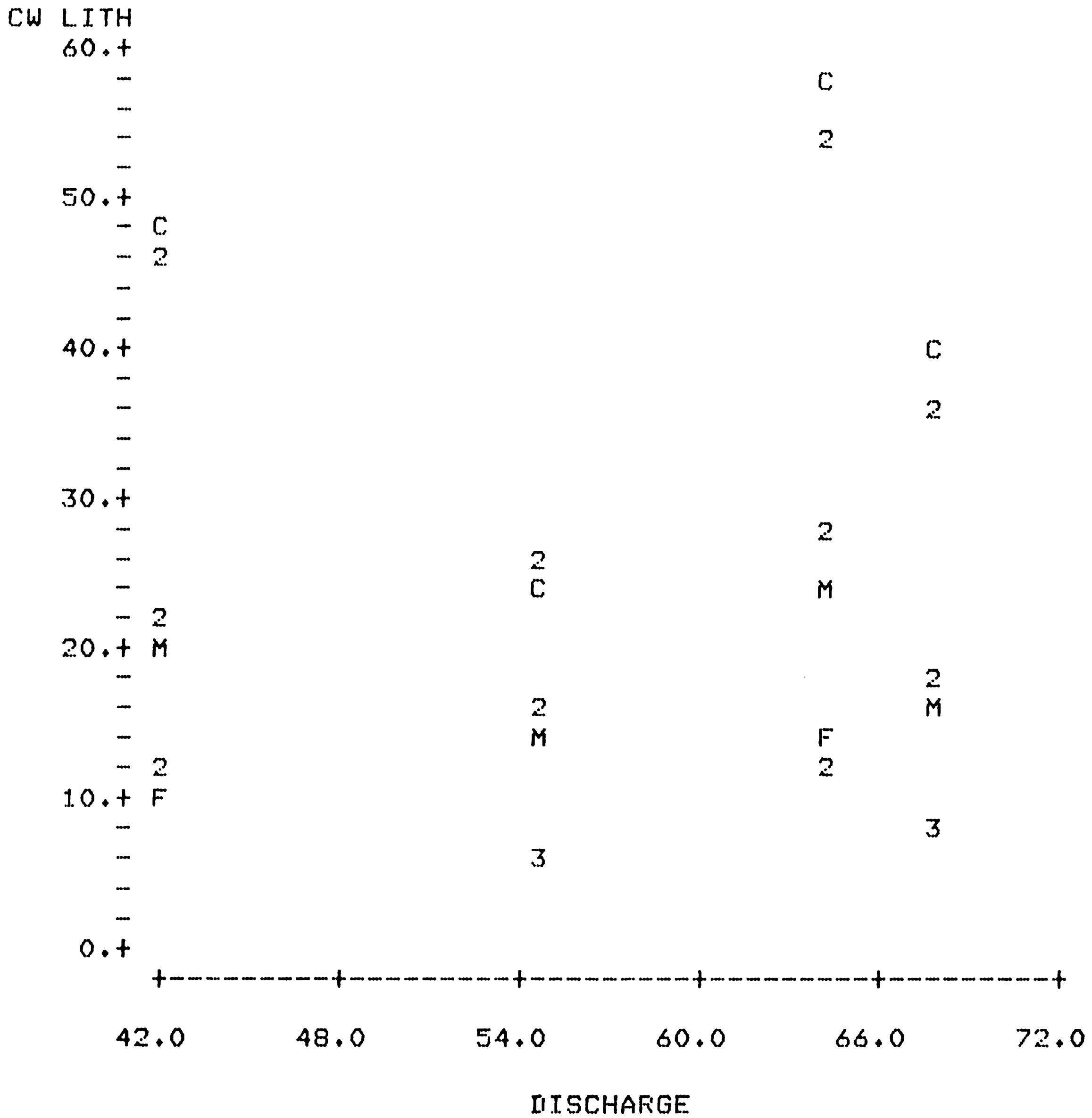
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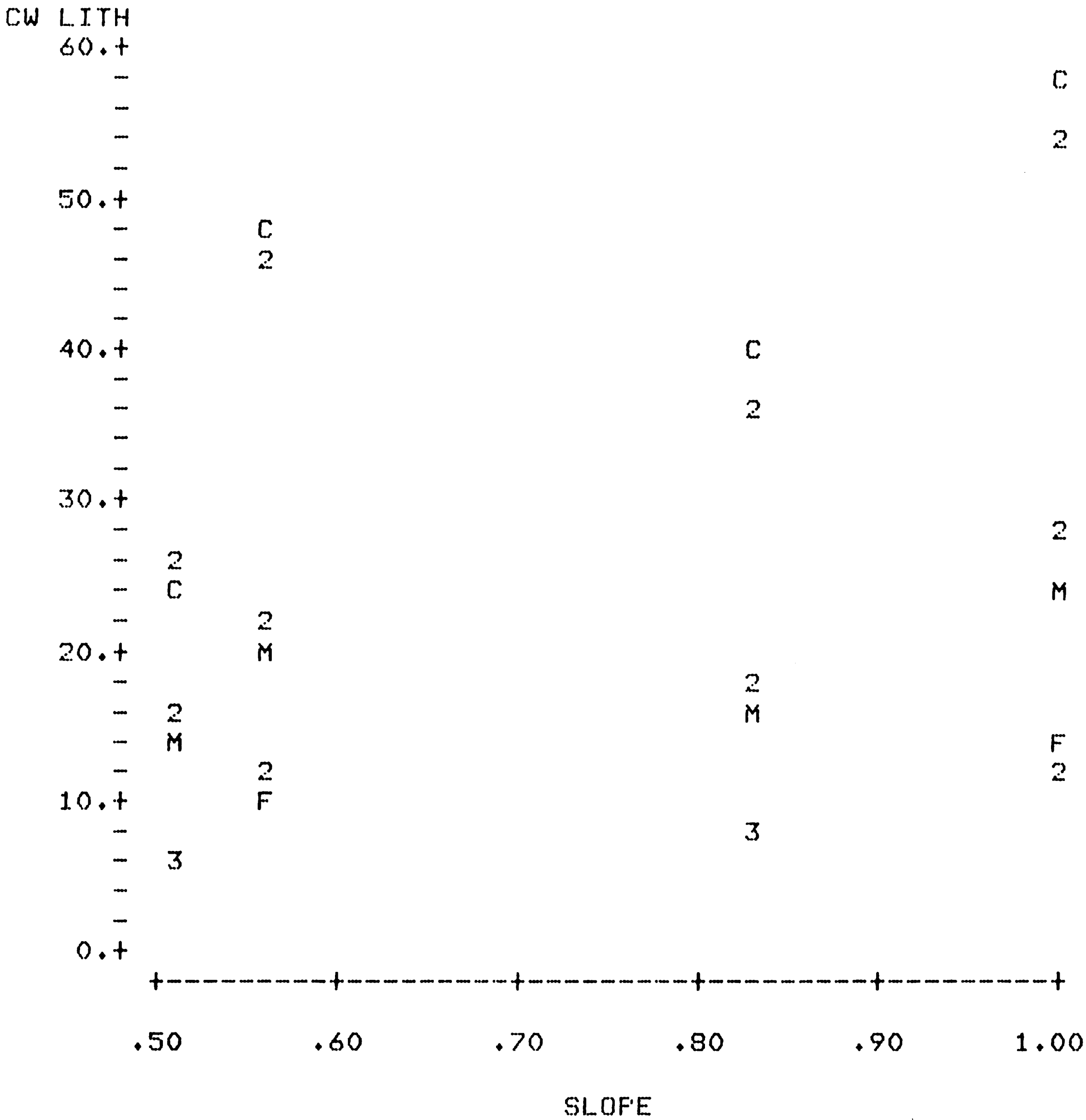
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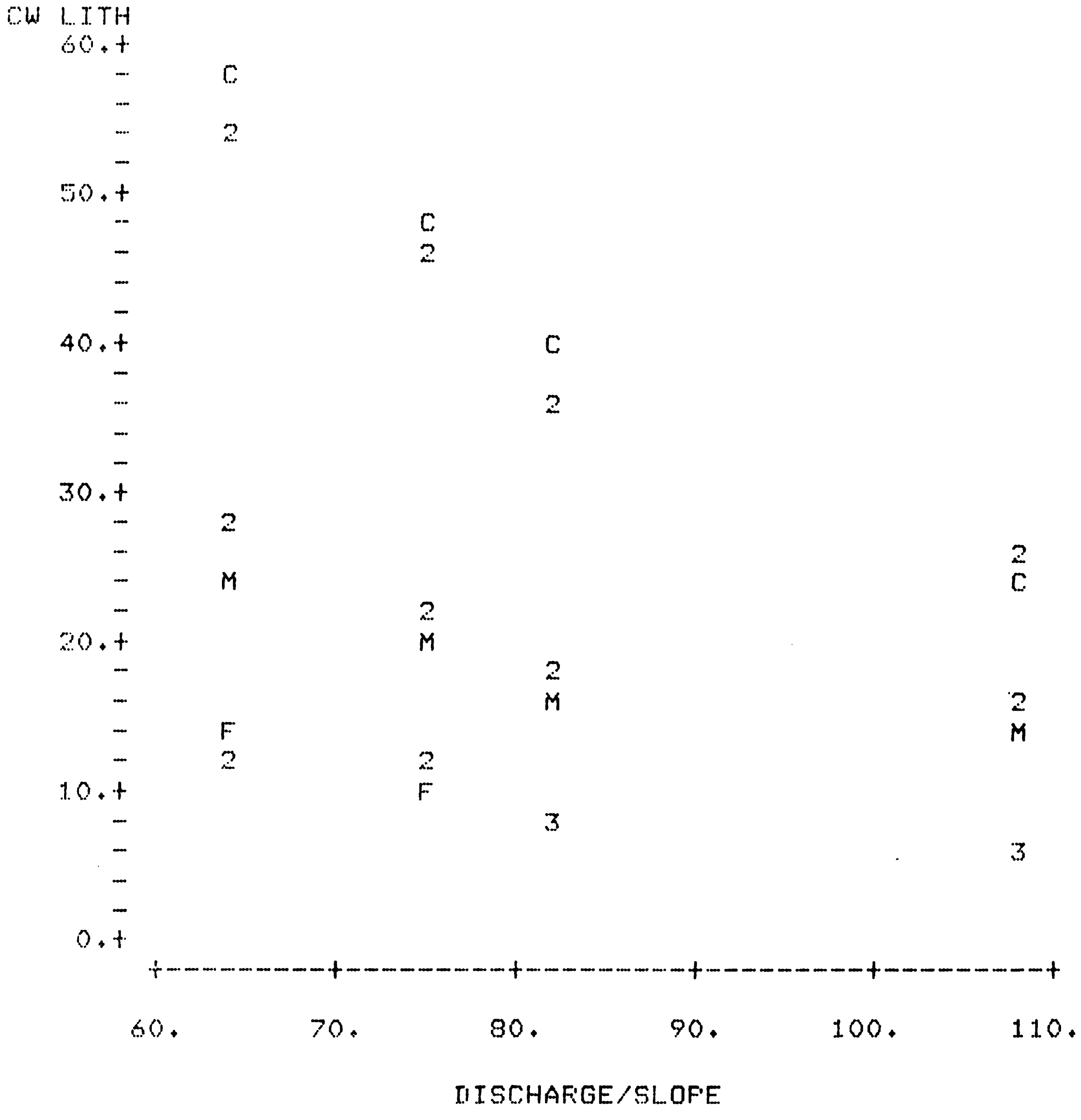
3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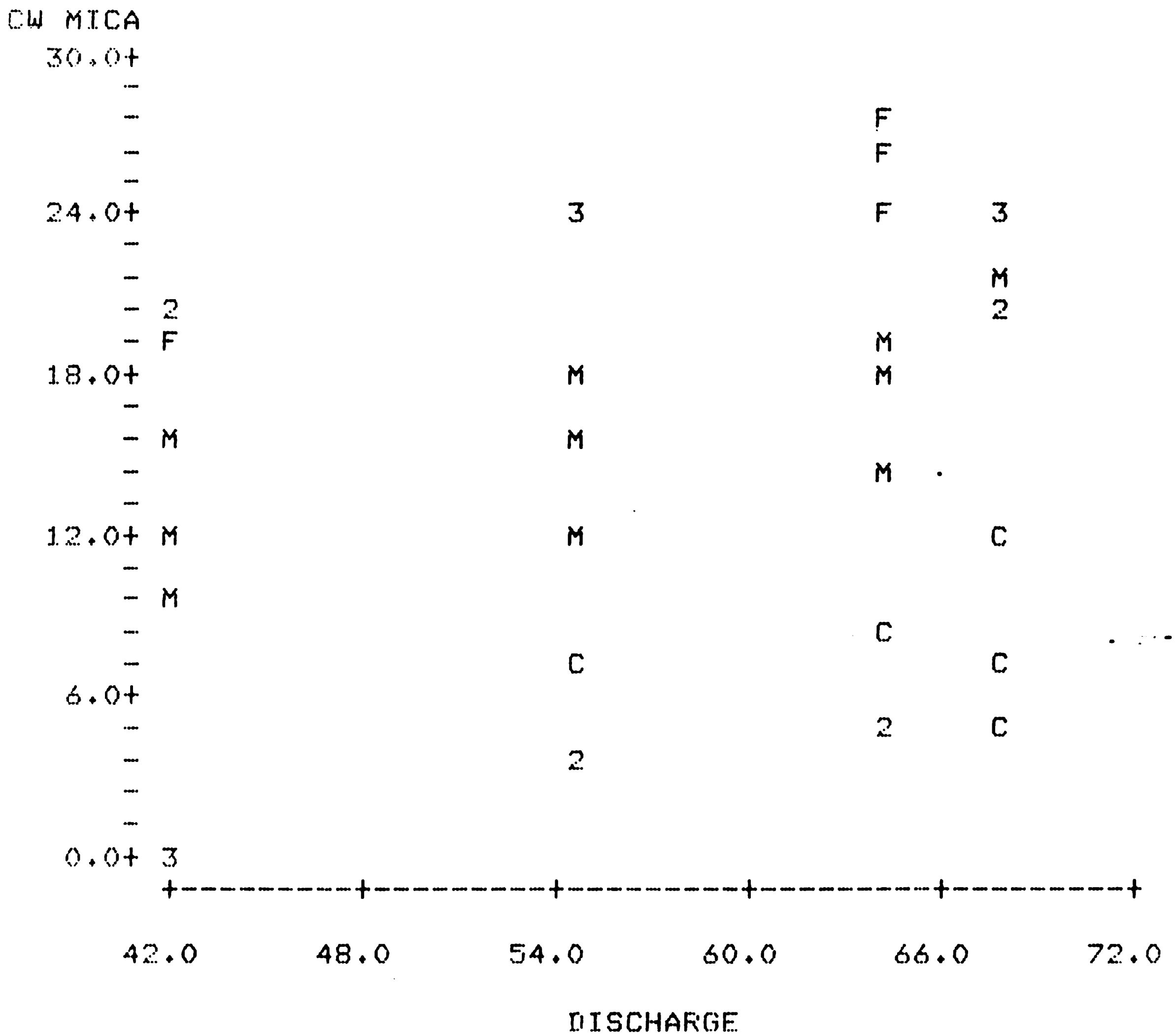
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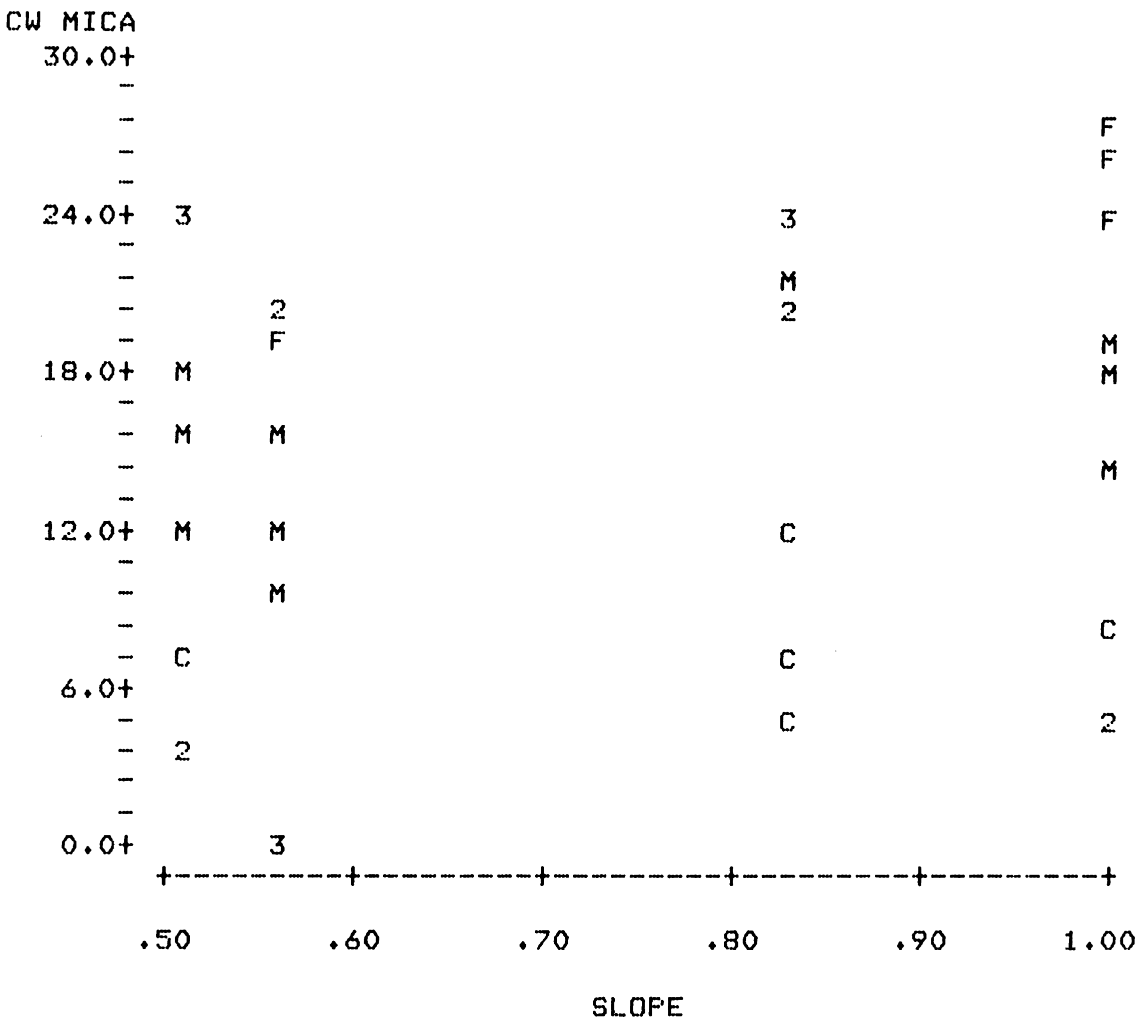
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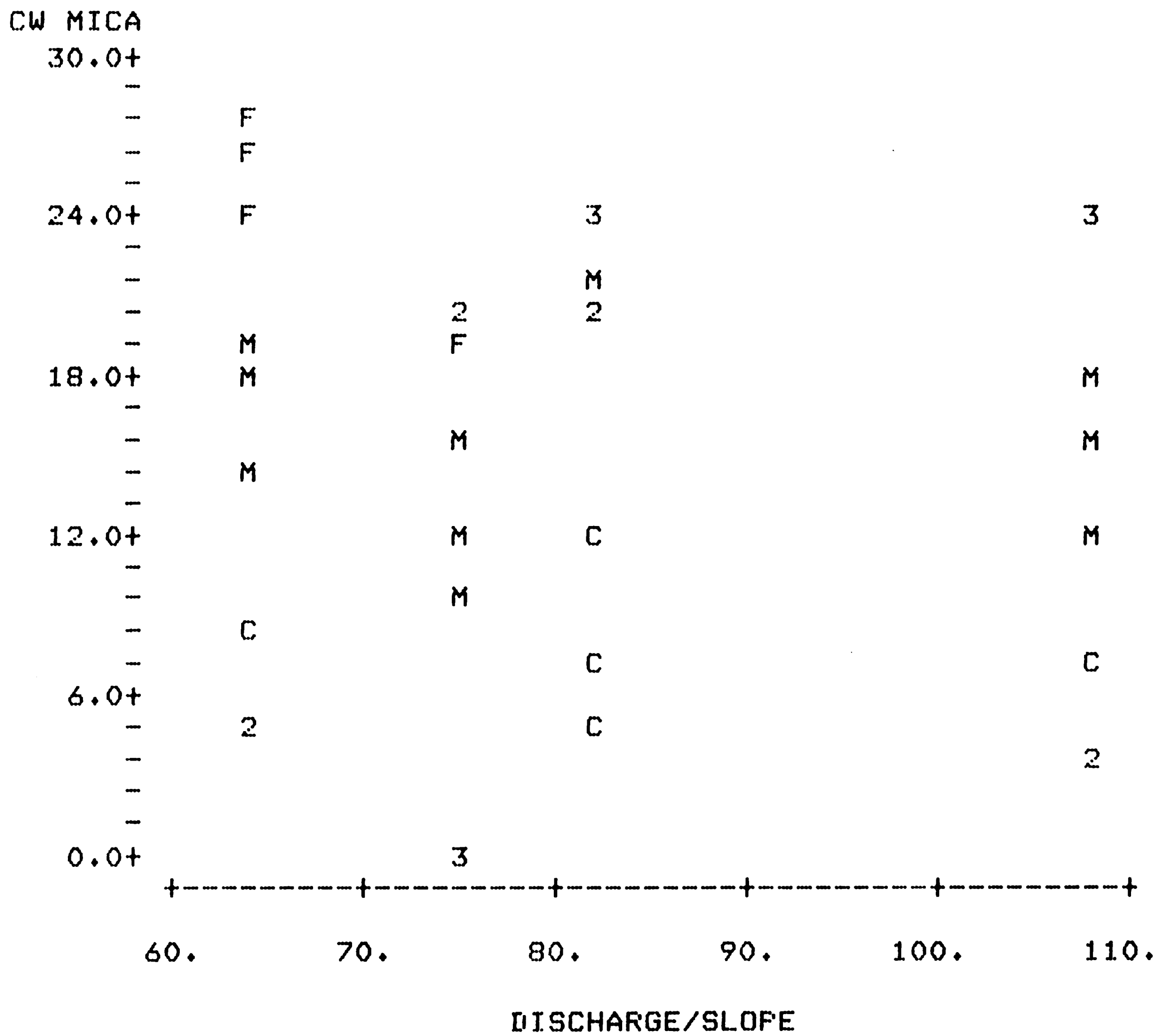
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DISCHARGE/SLOPE

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