მიეკუთვნება.

აგებულია სიკაშკაშის ცვალებადობის მრუდები სამივე ფერში. თითოეულ ფერში დახლოებით 80 დაკვირვება გვაქვს. ფერის მაჩვენებლის ცვლილება ამჟღავნებს ულტრაიისფერ სიჭარბეს ვარსკვლავის გამოსხივებაში. აგებულია დამოკიდებულებები (U,V), (V,B), (U-B,U), (B-V,U), (U-B,V) და (B-V,V) (ნახ.5,6). ჰერცშპრუნგ-რესელის დიაგრამაზე ვარსკვლავი T-ზოლის შიგნით თავსდება (ნახ.3). ორფეროვან დიაგრამაზე ყველა ინდივიდუალურ დაკვირვებას ვარსკვლავი მთავარი მიმდევრობის ხაზზე მიჰყავს, თუმცა ცალკეული დაკვირვებები შორდება მას (ნახ.4). სიკაშკაშის მომატებისას (U,U-B) - დიაგრამაზე შეიმჩნევა ულტრაიისფერი სიჭარბის ზრდა.

THREE-COLOUR PHOTOGRAPHIC PHOTOMETRY OF THE VARIABLE STAR BD+28°637

L.N.MOSIDZE

(Summary)

On the basis of three-colour photographic observational data obtained in 1960-64 the emission star BD+28°637 has been estimated to be a variable of the RW Aur type.

The light curves in three colours have been drawn (nearly 80 observations for each colour). The colour index variations indicate some ultraviolet excess of radiation to be present. The diagrams (U,V), (V,B), (U-B,U), (B-V,U), (U-B,V) and (B-V,V) have been drawn (fig.5,6,7). On the Hertzsprung-Russell diagram (fig.3) the star is situated inside the T-band. On the two-colour diagram all the individual observations bring the star to the main sequence line; although some of them noticeably depart from it on both sides (fig.4). The diagram (U,U-B) demonstrates some increase of ultraviolet excess while brightening of the star.

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БЮЛЛЕТЕНЬ АБАСТУМАНСКОЙ АСТРОФИЗИЧЕСКОЙ ОБСЕРВАТОРИИ № 39, 1970

AN INVESTIGATION OF THE 3600 - 4000 A REGION IN G5 - K5 STARS BY MEANS OF OBJECTIVE PRISM SPECTRA OF INTERMEDIATE DISPERSION

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Abstract. An investigation of the 3600 - 4000 A region in G and K stars (mainly giants) has been carried out by means of 194 objective prism spectra of dispersion 110 A/mm at 3900 A. Thirty-seven lines and bands in this spectral region were identified and their depths measured relative to two different straight-line continua. Ten additional points situated on peaks between the lines were also measured. Correlation coefficients between various spectral parameters (MK spectral class, (U-B), (B-V), M_V, C, C" and [Fe/H]) and the 1081 possible line depth ratios were computed. Then those line ratios that showed the largest correlations were selected. Finally, linear combinations of these line ratios from which the spectral parameters can be determined were established. This rather lengthy procedure implies that no major spectral criteriae could possibly be overlooked and that the adopted criteriae are really the best available for the present spectra.

The main result of the investigation is the establishment of a scheme for a quantitative spectral classification of the G5 - K5 stars at the present dispersion.

Especially, it is possible to determine the value of [Fe/H] for G8 - K3 giants with a mean error of 0.15.

For the spectral class and the luminosity, the optimal accuracy is found to be ± 1 subclass and $\pm 1^m$, respectively. The colour index (R - I), being an indicator of the effective temperature, can be determined with a mean error of $\pm 0^m.045$. No criteria for the MK spectral class and the luminosity have been found that are definitely better than those known in the blue spectral region. The possibility of determining [Fe/H] should therefore be the main reason for using the 3600 - 4000 A region in classification work on G5 - K5 stars at this dispersion.

1. Introduction. The 4000 - 4800 A spectral region has always been the most important in visual classification work on G and K stars by means of medium and low dispersion spectra (more than 100 A/mm). However, several investigators have added useful classification criteria related to features i the spectral region shortward of 4000 A.

After Lindblad's [1] discovery of the CN system with bandhead at 3883 A as being a sensitive luminosity indicator, much attention was given to the ultraviolet cyanogen bands. For a survey of the classification work carried out at the Uppsala an Stockholm observatories until 1946, cf. Lindblad [2]. Westerlun [3] continued the Swedish investigations and added several othe spectral criteria in the interval 3780 - 3900 A.

The 3883 A criterion was included in the Nassau - Seyfert classification scheme [4] on which McCuskey's work on stellar luminosities and space distributions is based [5]. Further criteria in the ultraviolet region were included in this scheme by Nassau and van Albada [6].

In his low dispersion investigations of stars in the North Galactic Pole region, Upgren [7] made use of several classification criteria down to 3550 A.

Morgan [8] obtained integrated spectra of globular cluster and demonstrated that the ratio of the continuum intensities around 3889 A correlated well with the metal abundances. Van den Bergh [9] made spectral scans of G dwarfs with a resolution of 20 A and found that this ratio was also a very good metal abundance indicator for these stars. McCarthy et al. [10] obtained objective prism spectra of G dwarfs (54 A/mm at 3900 A) and confirmed the sensitivity of Morgans criterion by visual inspection of microphotometer recordings. They also investigated some spectra of G8 giants, but they stated that the ultraviolet region did not reveal "any striking parameters although there is a possibility of meaningful differences in the features noted at 3780 and 3850 A and in the spectral interval between the K-line and 3889 A".

Walker [11] spectrophotometrically measured the 3883 A bandhead relative to two neighbouring regions for G and K stars. He found a strong correlation with similar measurements of the 4215 A cyanogen band [12] and noticed that the 3883 measurements showed a slight correlation with the weak-line and strong-line classes defined by Roman [13].

The present paper describes an investigation of the spectral region 3600 - 4000 A of G5 - K5 stars by means of objective

prism spectra of intermediate dispersion (110 A/mm at 3900 A). As shown by van den Bergh and McCarthy et al. there are sensitive metal indicators in this region of the spectra of G dwarfs. Therefore, it might be advantageous to investigate the possibility of such indicators also for G and K giants which, contrary to the dwarfs, could be used in a future investigation of the distribution of the metal in the Galaxy. Reliable [Fe/H] values for the calibration of metal-content sensitive spectral criteria are now available for several late type giants. The three-dimensional classification of G and K giants by Gyldenkerne [14] and the extension of this work which is now under way at the Copenhagen Observatory also furnish an important calibration material.

In order to make the investigation of this spectral region more complete, it was decided to search not only for metallicity criteria, but also to include the two other fundamental parameters for stellar classification work, the spectral class and the luminosity. This search was carried out by means of an electronic computer and involved the computation of all ratios between the depths of easily observable lines in the 3600 - 4000 A region. It is believed that no major spectral criteriae have escaped attention and, accordingly, that the search is complete for the spectral region and the spectral parameters.

The observations, the calibration of the plates and the recording of the spectra are described in Sections 2, 3 and 4. Since no tables of the features visible in spectra of late type stars in the 3600 - 4000 A region at this dispersion are available, wavelengths have been determined and the features subsequently identified in Section 5. The measurements of the recordings and the search for line-depth ratios usable for classification purposes are discussed in Sections 6 and 7. In Section 8 a classification scheme is proposed for ultraviolet spectra at the present dispersion of G5 - K5 stars. Finally, the conclusions are given in Section 9.

2. The observations. 194 ultraviolet objective prism spectra of 118 late-type stars have been obtained during the 1966-67 season by means of the 70 cm Abastumani menisc telescope equipped with an 8° prism. The stars were of spectral classes G5 - K5, except for two G2 stars, one M0 star and one M2 star. 17 stars were of luminosity classes Ib or II, 81 stars of classes II - III, III or III - IV and 20 stars of classes IV or V.

The selection of program stars was made in order to have as many as possible with known values of the following parameters: (U-B), (B-V), (R-I), M_V, C, C" and [Fe/H] . C is a measure of the metal content (Gyldenkerne, [14]). C", a parameter similar to C, has been calculated from new values of the spectral indices n, k and m given by Dickow et al. [15]. The program stars are given in Table 1.

The values of the parameters in columns 3 - 10 of Table 1 were taken from the following sources:

MK - type: Hoffleit [16]; Jaschek et al. [17];
(B-V),(U-B): Johnson et al. [18]; Argue [19]; Argue [20];
(R - I): Johnson et al. [18]; Argue [21];
Four stars had their (R-I) computed from Stebbins-Kron six-colour $(R-I)_6$ by means of $(R-I) = 0.83\ (R-I)_6 + 0.383$;
M_V: M_V (π) from Jenkins [22] for dwarfs, else M_V (K) from Wilson [23];
C: Gyldenkerne [14];
C": Computed as $C'' = n + 1.1k + 0.67m + \mathrm{const.}$ from Dickow et al. [15];
Fe/H: Helfer and Wallerstein [24];

In the two last columns are given the number of spectra a the plate numbers, referring to the platelibrary in Abastumani. Notice also the comments to Table 1.

For practical and economical reasons the brighter program stars were collected into groups of three, so that every group consisted of stars which were close in right ascension and of nearly the same U - magnitude in the standard UBV system. The spectra of the three stars were then obtained on the same plate. It was originally intended to observe two spectra of each star. The exposures were made as near as possible to the meridian on different nights. The succession of the observations of the three stars was reversed in the two exposures in order to minimize the effects of pre- and postexposure. A screening device, such as the one in use at Castel Gandolfo (cf.McCarthy et al., [10]), would have been advantageous, but was not accessible.

The spectra were obtained on Kadak IIa - O plated and covered the 3600 - 4900 A region, but only the 3600 - 4000 A region was exposed to normal density. The dispersion is given in Table 2. All spectra were widened to 0.3 mm. By means of two variable diaphragms in front of the objective prism, the exposure time was kept constant (5 min) for all stars brighter than $m_V = 7^m.5$.

Six plates,each with three exposed stellar spectra, and one exposed calibration plate (see Section 4) were developed simultaneously at 20°C in a Kodak D76 standard developer bath during 11 min. They were washed and fixed during 15 min in a standard fixing bath. Due to the minimal dust content of the air in Abastumani, the plates could be dried freely without any special precautions.

Only spectra of high and medium quality were used in this research.

3. The calibration. All plates IIa - O had the same emulsion number, but the calibration plate was always taken from the same box as the plates to be calibrated.

A few hours before development the calibration plate was exposed to a wide-band standard spectral lamp through a ISP-51 spectrograph. By inserting a thin foil stepfilter, nine spectra of the standard lamp with known intensity ratios were exposed on the calibration plate. Due to the small emission power of the standard lamp shortward of 4000 A, the spectra covered only the region 4000 - 4900 A (the upper limit is the plate limit). The precise wave-lengths in the spectra were found from a calibration made on the spectrograph. On every calibration plate two sets of spectra of different intensities were exposed with a common exposure time of 30 sec which was assumed to equal the effective exposure time at the telescope. The calibration plate was developed together with six spectral plates and hereafter a common calibration curve, determined from this calibration plate, was used for the six plates.

The calibration plate was scanned at a MF4 microphotometer in Abastumani. Scans were performed in a direction perpendicular to the spectral dispersion at 4050 A and the density across the 18 spectra of the standard lamp were recorded. The final calibration curve for 4050 A was obtained by displacing the two density curves along the log I - axis in a (log I, density) - diagram. The two curves could always be brought into good coincidence.

Since the standard lamp had only a small emission power below 4000 A, calibration curves could not be established at shorter wave-lengths. Hereby a systematic effect could have been introduced. It can, however, be judged from Kodak diagrams (kindly made available by Mr. J.Rossen) that the change in the calibration curve will not be large when going from 4050 A to, say, 3800 A. Furthermore, by intercomparison of all calibration curves obtained at 4050 A, only very slight differences have been noticed. It is therefore believed that the adopted procedure is safe and that only very small errors of differential nature have possibly entered at this point.

4. The recording of the spectra. The spectra were scanned at the MF4 microphotometer. The calibration curve was represented in an electronic device (cf.Kotlyar, [25]) and the spectra were recorded directly in intensity on a pen recorder. The scanning rate was 0.49 mm/min. For the interval 4050 - 3600 A this makes a total of 20 min. for one spectrum, including the recording of zero current and plate background. The spectra were projected on a slit (0.3 mm) and magnified 21 x, so that the slitwidth was equal to 1.6 A at 3900 A. The galvanometer constant was 0.7 sec, corresponding to 0.63 A at 3900 A for this scanning rate.

5. Identification of the lines. Most of the spectra are overexposed above 4050 A and underexposed below 3600 A. Between these wave-lengths a great number of lines and bands are visible. Due to the lack of any table of spectral features in ultraviolet spectra of G and K stars at the present dispersion an identification was carried out in the following way.

Thirteen spectra of the highest quality of spectral classes G5 to K5 and luminosity classes Ib to V were picked out. All visible lines between 4000 A and 3600 A were measured with a micrometer at the Copenhagen Observatory. Starting with ten easily identifiable lines from 3968 A to 3619 A (marked by an "x" in Table 3), approximate wave-lengths were computed by means of a least-squares Hartmann-method for all lines. Thirty-seven lines were selected that were easily observable in all thirteen spectra. By further identification of some of the lines, the Hartmann constants could be improved and, finally, all 37 lines were identified. The accuracy of the wave-length determination depended somewhat on the width of the line but was close to ± 0.4 A (m.e.). The identification was mainly based on Warner's [26] table for K0 III stars.Checks were performed by means of the few other existing tables of ultraviolet lines in spectra of late-type stars (for reference, cf.Merill,[27]). These tables as well as Warner's were all compiled at much higher dispersions (6 - 30 A/mm at H_r) than the present one (166 A/mm at H_r).

The thirty-seven lines are listed in Table 3 (lines nos. 6 - 42) and are shown by the vertical lines under the spectrum in Fig.1. Many of them consist of several components. In Table 3 are only given those that are believed to be the most important. It was noticed that in some high-quality spectra certain lines were resolved in two or more components. Since this was not the case for spectra that were of medium quality, these lines were considered as unresolved in all cases.

As mentioned in Section 1, the region 3900 - 3800 A in the spectra of G dwarfs contains features that are sensitive to the metal content. In the present work - which is primarily an investigation of giants - it was considered of importance not only to measure the above mentioned thirty-seven lines but also to include several points on the peaks between the lines. Therefore a total of ten more points were added (cf.Table 3, lines nos. 43 - 52). They are shown by the vertical lines above the spectrum in Fig.1. The lines were numbered from 6 and onwards for programming reasons.

6. Measurements of the line depths. The "continuum". Since a continuum in the physical sence of the word could certainly not be drawn, it was decided to place two quasi-continua in a consistent way. In what follows they are denoted by CONT I and CONT II (cf. Fig.1).

CONT I was drawn as a straight line,connecting two points, one at 4020 A and the other near 3680 A. The position of the last mentioned point depended somewhat on the spectral type. It was chosen so thaz the straight line only touched the spectrum in the two defining points and was above the spectrum elsewhere. CONT II was drawn as a straight line from the peak between the H and K lines and intersecting CONT I in its lower defining point. In some spectra, the region above 4000 A was overexposed and CONT I could not be drawn.

The measurements on the recordings of the depths at the fourty-seven points were carried out for 151 spectra in case CONT I and for all recorded spectra in case CONT II. For the 151 spectra the line depths corresponding to CONT II were automatically transferred from CONT I by means of an electronic computer. In case of plate errors or difficulties in localizing the line bottom, the line was not measured. In some cases the bottoms of certain strong lines and of lines below 3650 A were underexposed. These lines were also disregarded.

7. The establishment of spectral criteria. The following analysis, the purpose of which was to find usable criteris for the spectral parameters, was based on the line depths measured at the fourty-seven

points shown in Fig.1 and tabulated in Table 3.

The recorded spectra were divided into 18 groups; groups 1-9 corresponding to CONT I and groups 11 - 19 corresponding to CONT II. The number of spectra and the characteristics of each group are given in Table 4.

Correlation coefficients between the 1081 (= 47 x 23) possible line-depth ratios and various spectral parameters were computed by means of an IBM 7094 computer. The parameters were: MK spectral class*), (B-V), (U-B), (R-I), M_V, C, C" and [Fe/H]. The crosses in Table 4 indicate for which parameters and groups these computations were carried out.

When the correlation coefficient between a spectral parameter and a given line ratio exceeded a certain numerical value a print-out was made of the numbers of the lines in the line ratio, the correlation coefficient, the number of spectra, the coefficients for the regression line, the standard deviation and some other constants. Then, among these line ratios, those that seemed most promising (the "best" ones) were handpicked according to the selection criteria given below.

Table 5 contains the two line-depth ratios assumed to be the best in each case. The columns of Table 5 are as follows:

1) the group number (cf. Table 4)
2) the number (n1) of spectra with observed (Table 1) values of the parameter in question
3) the two best line ratios (numbers referring to Table
4) the numbers (n2) of spectra with observed values of the parameter and for which the lines in the line ratio were measured
5) the number (n3) of spectra for which the residual between the observed and computed value of the parameter exceeded twice the standard deviation around the regression line
6) the standard deviation $\varepsilon = (\Sigma\,(0 - C)^2/\,(n2-n3-2))^{1/2}$, where (0 - C) means the observed minus the computed value of the parameter and the summation does not include those spectra for which the condition in column 5 is fulfilled.

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*) The code is: G0 = 5.0, G5 = 5.5, K0 = 6.0, K5 = 6.5 and M0 = 6.6 etc.

Thus ε is a measure of the external accuracy in the determination of the spectral parameters by means of the present method. The exclusion of a few, greatly deviating values is of importance when a preliminary analysis like this one is carried out by an automatic computer, so that the computed ε's are not seriously influenced by gross errors.

The criteria according to which the "best" line ratios were selected were:

1) ε as small as possible.
2) n2 as large as possible, i.e. the lines entering the line ratio being measurable in as many spectra as possible
3) n3 as small as possible.

In some cases measuring errors were detected when a spectrum fulfilled the condition for exclusion. These errors were corrected and the computations repeated.

The computations so far involved only one line-ratio at a time. Since a combination of line ratios might yield better results, a further investigation was carried out for some of the spectral parameters. According to the above mentioned selection criteria the five to eight best line ratios were selected. With the GIER computer at the Copenhagen Observatory all possible linear combinations of these line ratios were investigated by means of a least-squares program. Again the best combination could be selected according to the following natural criteria:

1) ε as small as possible
2) not more than two or three line ratios in the combination with due regard to the size of ε
3) the line ratios in the combination should be measured in as many spectra as possible, i.e. be generally easy to measure.

In Table 6 are given the "best" combinations. They are believed to represent the most usable criteria for the spectral parameters in connection with the spectra that are investigated here. The columns are:

1) The group number (cf.Table 4)
2) the number (n) of spectra with known values of the spectral parameter and for which the lines in the combination were measured.
3) the linear combination of line ratios from which the spectral parameter is computed and the computed mean errors of the coefficients
4) the external mean error $\varepsilon_{ext} = (\Sigma(0-C)^2/(n-m))^{1/2}$, where m is the number of coefficients in the combination.

Here again (O-C) is the difference between the observed and the computed value of the parameter

5) the internal mean error $\varepsilon_{int} = (\Sigma v^2/(n_{sp} - n_{st}))^{1/2}$, where v is the deviation of a computed value from the mean value of a spectral parameter of a star. The summation is carried out over all spectra of stars with two or more spectra
6) the number (n_{st}) of stars with two or more spectra
7) the total number (n_{sp}) of these spectra.

It must here be recalled that ε_{ext} in Table 6 includes all spectra, whereas some spectra for the above explained reason were excluded in the computation of ε in Table 5.

For a given spectral parameter, ε_{int} would be expected to be about the same for all groups. Although this if not the case - partly due to the statistically small values of n_{st} and n_{sp} (columns 6 and 7 in Table 6) - it is hereby possible to get a good idea of the internal accuracy of the observational material.

In what follows the results (cf. Table 6) for the various parameters is discussed.

MK spectral class.

The spectral class is a non-continuous spectral parameter with a class interval of 1 subclass, and the MK classes that have been used here are visually estimated by various authors. Therefore ε_{ext} cannot possibly be much below 1 subclass. The value of ε_{int} goes from 0.4 to 0.9 subclass. The obtainable internal accuracy with the present method is therefore probably somewhat higher than that of visual classification in the blue region, at least if the stars have been separated according to luminosity (groups 1, 2, 5, 11, 12 and 15), cf. Section 8.

The extremely metal-poor star HD 221170 (G2 according to Wallerstein and Helfer, [28]) apparently does not fit the scheme; according to the line ratio combination for group 19, the MK spectral classes for four spectra were found close to K0. It was therefore excluded when the external error was computed.

The results for the MK spectral class are shown in Figures 2a to 2h.

From figures 2d and 2h we notice that the class Ib stars fall somewhat off the main line. Principally, it is then not possible to determine the MK spectral classes for a star by means of the formulae for groups 9 and 19 unless it is known not to be a supergiant. However, it will later be shown that this

restriction does not present any real difficulties.

(U - B), (B - V) and (R - I).

(U-B), (B-V) and (R-I) were included in the present investigation as examples of continuous spectral parameters. The values of ε for (U-B) and (B-V) in Table 5 were rather high and no further analysis was done on (U-B) and (B-V).

(R-I) looked more promising and improved combinations of line ratios were computed. From Table 6b it is seen that ε_{ext} for groups 1, 2, 5, 11, 12 and 15 are between $0^m.032$ and $0^m.049$. The results are shown graphically in Figures 3a to 3f. Linear combinations were also computed for groups 9 and 19 but only giants and supergiants followed the regression line; the $(R-I)_{AB}$ for dwarfs computed by the formulae for groups 9 and 19 are systematically too high. Thus, (R-I) as a good indicator of the effective temperature (calibrated by Johnson, [29]), can be determined with a mean error of about ± $0^m.045$ if the luminosity class is known. It should be noticed that the spread in the values of (R-I) for the dwarfs is not very large (cf. Figures 3c and 3f).

M_V.

The reliability of $M_V(K)$ has been questioned by Hodge and Wallerstein [30], Wallerstein [31] and the present author (West, [32]). It seems as if the calibration for the giants could be in error by a few tenths of a magnitude. However, the use of $M_V(K)$ as a luminosity indicator is justified here, first because it is the only quantitative parameter known for the late-type giants, and second because the eventual systematic errors are much less than the obtained mean error ($\sim 1^m$).

Some difficulties were encountered during the M_V calibration. First, computations were carried out including stars of luminosity classes I and II. But it did not seem possible to distinguish between the supergiants and the giants, since all combinations of line ratios that separated dwarfs and giants were strongly curved towards higher luminosities and almost invariably placed all supergiants around $M_V = \bar{V}1^m$. It might have been possible to solve this problem by the inclusion of quadratic terms in the line-ratio combinations, but this was considered to be too large an extension of the analysis at this stage. It was therefore decided to investigate the dwarfs and giants only.

The optimal values of ε_{ext} ranged from $0^m.52$ for group 6 to $1^m.29$ for group 7. Groups 9 and 19 showed very large values of ε in Table 5, and no further analysis was performed. The values of ε_{int} for groups 6 and 16 are exceptionally low and ca not be considered real. A possible explanation is the distribut on of M_V values in these groups. From the other groups we get t more reasonable value range of $0\overset{m}{.}7$ to $0\overset{m}{.}9$. With the values of ε_{ext} and the commonly accepted mean error of a $M_V(K)$ value, $\pm 0\overset{m}{.}3$, there is still some cosmical scatter left. Probably the true value of ε_{int} is about $0\overset{m}{.}9$. The results for groups 6, 7, 16, 17 and 18 are shown in Figs. 4a to 4f.

Although supergiants cannot be separated by the present line-ratio technique, it is easy to do this by visual inspection. For supergiants the break around 4000 A is much greater than for normal giants, cf. Figure 5. By means of this criterion it is possible to pick out supergiants in advance of an analysis.

C and C".

Basically, C and C" are measures of the metal content, although a recent investigation (Rasmussen, [33]) has revealed that they are somewhat influenced by other parameters. The observed interval for C" extends from 1.200 to 1.500 which is about three times the interval of C (0.330 - 0.420). The values of ε_{ext}(C) and ε_{ext}(C") are in about the same ratio, indicating that no further gain in accuracy is obtained when changing from C to C" as calibrating parameter.

The results for C and C" are given in Figures 6a to 6d.

[Fe/H].

When the observational program was compiled in the spring of 1966, spectroscopically well determined values of [Fe/H] had only been published for a few late-type giants. Therefore the basis for the calibration is not very extensive. Two stars, HD 168322 and HD 219615, had [Fe/H] values from Greenstein and Keenan [34]. These values were corrected with -0.5, according to investigation of Gyldenkerne (unpublished). Two K3 stars with known [Fe/H] values were included into group 3 and 13 in this calibration.

The results for [Fe/H] are given in Figures 7a and 7b.

Since the original basis for [Fe/H] was rather small, a further check of the reliability was desirable. A comparison has therefore been carried out between $[Fe/H]_{AB}$, determined by some of the present line ratios and $[Fe/H]_{pe}$, computed by Rasmussen [33] from the g and m indices in the catalogue by Dickow et al. [15].

In Table 7 are shown the linear expressions by which $[Fe/H]_{AB}$ was computed, the number (n) of spectra for which $[Fe/H]_{pe}$ was known and the standard deviation for ($[Fe/H]_{pe}$ - $[Fe/H]_{AB}$). See also Figs. 8a and 8b.

It is found that the standard deviation is about the same as the stated mean error of a high dispersion [Fe/H] value ±0.15.

The calibration of the $[Fe/H]_{pe}$ has been carried out on the basis of a material of 24 highly selected stars with high dispersion values of [Fe/H]. The linear combination of g and m by which $[Fe/H]_{pe}$ is computed does not depend on the (R-I) and M_V values and is therefore a pure measure of the metal content. The very good agreement between $[Fe/H]_{pe}$ and $[Fe/H]_{AB}$ that is demonstrated in figs. 8a and 8b strongly supports the conclusion that the metal content of G8 - K3 giants can be determined by means of the present objective prism spectra.

If the standard deviation shown in Table 7 fully belongs to our $[Fe/H]_{AB}$ values, then a classification of G8 - K3 giants into at least three [Fe/H] classes for stars in the interval $0 > [Fe/H] > -1.0$ is possible by the line-ratio method.

8. The determination of spectral parameters. It is suggested that a determination of the MK spectral class, M_V, [Fe/H] and (R-I) of a G5 - K5 star by means of spectra taken under the same conditions as the present ones is carried out in the following way:

Given a recorded spectrum (ordinate: log I). By visual inspection make sure it is in the range G5 - K5. Place CONT I (or CONT II). If it is not a supergiant (according to the break at 4000 A cf. Fig.5) then find the MK spectral class from the formula for group 9 (19). Depending upon the MK class, find M_V from the formulae for groups 6, 7 or 8 (16, 17 or 18). Find the improved spectral class from the formulae for group 1 (if it was a supergiant), 2 or 5 (11, 12 or 15). If the star is a giant in the range G8 - K3, then [Fe/H] can be determined from the formula for group 3 (or 13). Finally, (R-I) can be determined from the formulae for groups 1, 2 or 5 (11, 12 or 15). The effective temperature is then found from Johnson's [29] calibration.

9. Conclusions. An investigation of the 3600 - 4000 A region in the spectra of G8 - K3 stars and a search for features sensitive to various spectral parameters have been carried out by means of spectra of dispersion 110 A/mm at 3900 A. The apparent optimal classification scheme for this re-

gion is given in Section 8. It is now valuable to compare the results with those already known for the blue region.

In the present classification scheme the obtainable accuracy in the MK spectral class and M_V is about ± 1 subclass and ± 1^m, respectively. It is nearly the same for CONT I and CONT II, indicating that no serious losses in accuracy are encountered when drawing a straight-line continuum in different ways.

It is concluded that there does not seem to exist any criteria for the spectral class and the luminosity in the 3600 - 4000 A region definitely better than those already known in the blue region above 4000 A.

An important result of this investigation is the possibility of determining the value of [Fe/H] for G8 - K3 giants with a mean error of ± 0.15. This accuracy corresponds to a class-division into three or four metal-content classes in the interval 0 > [Fe/H] > -1.0. In this work the limiting U-magnitude is close to $11^m.2$. For a K0 III star with $M_V = +1^m$ and (U-V) = $1^m.93$ (according to Johnson, [29]) this corresponds to a limiting distance of 460 pc. A large-scale investigation of the distribution of the metal content of late-type giant stars would therefore be possible on the basis of the present result.

Acknowledgements. The observations and the preliminary reductions were made at the Astrophysical Observatory of the Georgian Academy of Sciences in Abastumani during my stay from August 1966 to February 1967. The rest of the work was done at the Copenhagen Observatory.

This project could not have been carried through without the support of the following people and institutions to whom I hereby express my sincere gratitude.

Professor A. Reiz of the Copenhagen Observatory took the initiative for my stay in Abastumani which was made according to the exchange program between Denmark and the Soviet Union with the permission of the Copenhagen University and the Soviet and Georgian Academies of Sciences. The expenses were covered by a grant from "Observator Julie M. Vinter Hansens Rejselegat". In Abastumani Professor E.K.Kharadze effectively supported me by fruitful discussions and continuous encouragement. Drs. R.A.Bartaya and M.A.Shiukashvili and other members of the staff helped me with many practical advices during the observations. In Copenhagen Mr. P. Kjaergaard Rasmussen furnished me with [Fe/H] values in advance of publication. Finally, I had some interesting discussions with dr. K. Gyldenkerne.

Some of the computations were done at the GIER computer at the Copenhagen Observatory which had been made available by the Carlsberg Foundation. The correlation coefficients were computed on the IBM 7094 computer at the Northern Europe University Computing Center at the Technical University in Copenhagen.

August, 1969.

G5 - K5 ვარსკვლავთა სპექტრული უბნის 3600-4000 Å გამოკვლევა ობიექტივიანი პრიზმით მიღებული ზომიერი დისპერსიის სპექტრების მეშვეობით

რიჩარდ მ. ვესტი (კოპენჰაგენის ობსერვატორია)

(რეზიუმე)

G5-K5 ვარსკვლავთათვის, 118 სტანდარტი ვარსკვლავის გამოყენებით (ცხრ.1),აბასთუმნის ობსერვატორიის 70-სმ მენისკურ ტელესკოპზე 1966-67 წ.წ. 8°-ლიანი ობიექტივნის პრიზმით მიღებული სპექტრების საფუძველზე,ახლო ულტრაიისფერ უბანში 3600-4000 A /დისპერსია 110A/მმ 3900 A-თან/,განხორციელებულია ორგანზომილებიანი რაოდენობრივი კლასიფიკაცია /MK-სპ. კლასი;M_V/,მეტალურობის პარამეტრის [Fe/H] გათვალისწინებით.გამოკვლეულია აგრეთვე პარამეტრების U-B,B-V,R-I,C,C" განსაზღვრის შესაძლებლობანი.

შერჩეული და გაიგივებულია 37 სპექტრული ხაზი და დამატებით -10 პიკი მათ შორის /ნახ.1,ცხრ.3/.გამოსაკვლევი ვარსკვლავები დაჯგუფებულია სპექტრული კლასისა და აბსოლუტური სიდიდის მიხედვით /ცხრ.4/.ცალკეული ჯგუფებისათვის,გამოსათვლელი მანქანის გამოყენებით,გადასინჯულია ყველა შესაძლო ვარიანტი სპექტრული ხაზების ინტენსივობათა /ხაზთა სიღრმეების/ ისეთი ფარდობებისა,რომლებიც კორელაციაშია ამა თუ იმ საძიებელ პარამეტრთან.ამგვარად მოძებნილი კრიტერიუმებიდან /ცხრ.5/ შერჩეულია საუკეთესოები /ცხრ.6/ საბოლოო სარედუქციო მრუდების ასაგებად /ნახ. 2,3,4,6,7/.

სპექტრული უბანი 3600-4000 A სავსებით გამოსაყენებელი აღმოჩნდა ზემოჩამოთვლილ პარამეტრთა განსასაზღვრავად, ოღონდ,U-B,B-V, პარამეტრების გამორიცხვით.სპექტრული კლასისა და აბსოლუტური სიდიდის კრიტერიუმები ფოტოგრაფიულ უბანთან შედარებით სუსტია.მეტალურობის პარამეტრი [Fe/H],რომლის განსაზღვრის შესაძლებლობის დადგენა აღებული უბნის გამოკვლევის ძირითად მიზანს შეადგენდა,საკმაოდ კარგად განისაზღვრება.

ИССЛЕДОВАНИЕ СПЕКТРА ЗВЕЗД G5-K5 В УЧАСТКЕ 3600-4000 Å С ПОМОЩЬЮ СПЕКТРОВ УМЕРЕННОЙ ДИСПЕРСИИ, ПОЛУЧЕННЫХ С ПРЕДОБЪЕКТИВНОЙ ПРИЗМОЙ

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(Резюме)

Выполнена двумерная количественная спектральная классификация (МК-сп.класс; M_V) звезд типа G5-K5 в участке 3600-4000 А, с учетом параметра металличности [Fe/H]. Материалом послужили снимки, полученные в Абастумани на 70-см менисковом телескопе, снабженном 8^0-ой предобъективной призмой (дисперсия II0 A/мм около 3900 A). При этом использовано II8 стандартных звезд (табл.I). Исследованы также возможности определения параметров U-B, B-V, R-I, C, C".

Выделены и отождествлены спектральные линии в количестве 37 и, дополнительно, I0 пиков между ними (рис.I, табл.3). Исследуемые звезды сгруппированы по спектральным классам и абсолютным величинам (табл.4). Для отдельных групп, с применением вычислительной машины, рассмотрены все возможные варианты таких отношений интенсивностей спектральных линий (глубин линий), которые находятся в корреляции с теми или иными искомыми параметрами. Среди критериев, найденных таким способом (табл.5), избраны наилучшие (табл.6) для построения окончательных редукционных кривых (рис. 2,3,4,6,7).

Спектральный участок 3600-4000 А оказался вполне применимым для определения перечисленных выше параметров, исключая, однако, U-B и B-V. Критерии спектрального класса и абсолютной величины относительно слабы по сравнению с фотографическим участком. Параметр металличности [Fe/H], выяснение возможности определения которого составило основную цель исследования данного участка, определяется достаточно хорошо.

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Table 1

HR	HD	MK	(B-V)	(U-B)	(R-I)	M_V	C	C''	[Fe/H]	No.of spectra	Plates
8	166	KO V	+0.76	+0.35	-		-	+1.330	-	2	5796,5888
37	787	K5 III	+1.46	+1.63	-	-	-	-	-	1	5795
152	3346	K5 III	+1.60	+1.97	+0.950	-	-	-	-	2	5794,5857
163	3546	G8 III	+0.87	+0.47	+0.491	-	+0.346	+1.238	-0.75	3	5778,5887,5908
165	3627	K3 III	+1.28	+1.48	+0.645	-	-	-	-	2	5907,6051
166	3651	KO V	+0.85	+0.58	+0.390	-	+0.379	+1.298	-	2	5796,5888
167	3690	KO II-III	+1.07	-	-	-	-	-	-	1	5796
168	3712	KO II-III	+1.17	+1.12	+0.586	-	+0.400	+1.450	-	1	5843
175	3817	G8 III	+0.89	+0.60	+0.460	-	+0.379	+1.342	-	2	5780,5889
222	4628	K2 V	+0.88	+0.58	+0.477	-	-	+1.209	-	2	5796,5888
224	4656	K5 III	+1.51	+1.86	+0.849	-	-	-	-	2	5795,5858
253	5234	K2 III	+1.22	+1.26	+0.610	-	+0.389	+1.325	-	4	5778,5778,5887 5887
265	5395	G8 III-IV	+0.96	+0.69	+0.513	-	+0.341	+1.254	-	5	5778,5887,5887 5908,5908
267	5437	K4 III	+1.52	-	-	-	-	-			
279	5722	G7 III	-	-	-	-	-	-	-	3	5794,5857,5888
294	6186	KO III	+0.95	+0.71	+0.515	-	-	-	-	2	5794,5857
321	6582	G5 V	+0.69	+0.09	+0.414	-	+0.344	+1.282	-	2	5780,5889
434	9138	K4 III	+1.38	+1.53	+0.753	-	-	-	-	2	5889,5909
489	10380	K3 III	+1.36	+1.55	+0.716	-	-	-	-	1	5890
493	10476	K1 V	+0.84	+0.49	+0.431	-	-	-	-	1	5858
511	10780	KO V	+0.80	+0.40	+0.399	-	+0.359	+1.248	-	1	5890
552	11624	KO III	-	-	-	-	+0.400	+1.282	-	1	5890
556	11727	MO III	-	-	-	-	-	-	-	1	5911
617	12929	K2 III	+1.15	+1.13	+0.605	-	-	-	-	1	5911
649	13611	G8 II	+0.89	+0.60	+0.472	-	+0.359	+1.323	-	1	6054
824	17361	K1 III	+1.11	+1.07	+0.568	-	+0.372	+1.372	-	1	5859
834	17506	K3 Ib	+1.69	+1.92	+0.890	-	-	-	-	1	5859
857	17925	KO V	+0.87	+0.56	+0.450	-	-	+1.294	-	2	5860,5891
882	18449	K2 III	+1.24	+1.29	+0.638	-	+0.374	+1.310	-	1	5861
949	19735	K5 III	+1.44	+1.67	-	-	-	-	-	1	5860
951	19787	K2 III	+1.03	+0.88	+0.520	-	+0.391	+1.380	-	1	5892
996	20630	G5 V	+0.68	+0.19	+0.356	-	-	-	-	1	5892
999	20644	K4 III	+1.56	+1.82	+0.880	-	-	-	-	1	5861
1277	25975	K1 III	+0.94	+0.72	-	-	-	-	-	1	5860
1327	27022	G5 III	+0.81	+0.48	+0.424	-	-	-	-	1	5892
1452	29065	K4 II-III	+1.46	+1.70	-	-	-	-	-	1	5861
1457	29139	K5 III	+1.54	+1.92	+0.940	-	-	-	-	2	6065,6065
1577	31398	K3 II	+1.53	+1.78	+0.820	-	-	-	-	1	6054
1580	31421	K2 III	+1.16	+1.12	+0.630	-	+0.323	+1.294	-	1	5894
1907	37160	G8 III	+0.95	+0.64	+0.540	-	+0.346	+1.234	-0.73	1	5894
1963	37984	K1 III	+1.17	+1.07	+0.621	-	+0.340	+1.267	-	1	5895
1995	38656	G8 III	+0.94	+0.69	+0.490	-	+0.398	+1.315	-	1	5894
2002	38751	G8 III	+1.01	+0.82	+0.557	-	-	+1.476	-0.11	1	5895
2012	39003	KO III	+1.13	+1.08	+0.567	-	+0.392	+1.413	-	1	5894
2037	39400	K2 II	+1.38	+1.47	-	-	-	+1.380	-	1	5895
2077	40035	KO III	+0.99	+0.91	+0.482	-	+0.367	+1.331	-	1	6041
2219	43039	G8 III	+1.01	+0.81	+0.539	-	+0.334	+1.280	-0.42	1	6041
2473	48329	G8 Ib	+1.40	+1.47	+0.610	-	+0.425	+1.486	-	1	6041
2527	49878	K4 III	+1.36	+1.68	-	-	-	-	-	1	5864
-	50281	K4 V	+1.05	+.95	-	-	-	-	-	1	5864
-	50282	KO III	-	-	-	-	-	-	-	1	5896
4057-8	89484-5	KO III	+1.15	+1.00	+0.620	-	-	+1.261	-0.49	2	6048,6048
4301	95689	KO III	+1.07	+0.92	+0.580	-	-	+1.459	-0.23	2	6049,6049
6703	163993	G9 III	+0.94	+0.70	+0.460	-	+0.416	+1.429	-	3	5727,5784,5875
6705	164058	K5 III	+1.52	+1.88	+0.850	-	-	-	-	2	5783,5798
6770	165760	G8 III-IV	+0.97	+0.73	+0.500	-	-	+1.373	-	2	5785,5901
6791	166208	KO III	+0.91	+0.73	+0.441	-	-	+1.415	+0.02	2	5785,5901
6817	167042	K1 III	+0.95	+0.71	-	-	-	+1.305	-	1	5735

6840	167768	G8 III	+0.89	+0.55	-	-	-	+1.306	-	1	5735
6853	168322	G9 III	+0.98	+0.69	-	-	-	+1.223	-0.70	1	5735
6866	168656	G8 III	+0.91	+0.61	+0.450	-	-	+1.370	-	2	5785,5901
6872	168775	K2 III	+1.17	+1.19	+0.550	-	+0.389	+1.425	-	3	5727,5784,5875
6895	169414	K2 III	+1.18	+1.16	+0.600	-	+0.366	+1.322	-	2	5784,5875
-	170657	K3 V	-	-	-	-	+0.354	+1.231	-	2	5731,5745
7192	176670	K3 II	+1.47	+1.67	-	-	-	-	-	1	5800
7310	180711	G9 III	+1.01	+0.79	+0.510	-	+0.359	+1.316	-	3	5728,5783, 5798
7314	180809	KO II	+1.25	+1.23	+0.590	-	-	+1.449	-	2	5787,5876
7328	181276	KO III	+0.97	+0.74	+0.470	-	+0.388	+1.373	-	2	5877,5903
7368	182488	KO V	+0.81	+0.46	-	-	-	+1.317	-	1	5748
7373	182572	G8 IV	+0.76	+0.43	-	-	-	+1.367	-	2	5787,5876
7429	184406	K3 III	+1.18	+1.25	+0.610	-	-	-	+0.24	1	5800
7462	185144	KO V	+0.80	+0.37	+0.410	-	+0.379	+1.241	-	2	5744,5869
7468	185351	KO III	+0.94	+0.69	-	-	+0.392	+1.379	-	2	5787,5876
7525	186791	K3 II	+1.52	+1.68	+0.750	-	-	-	-	1	5878
7576	188056	K3 III	+1.27	+1.53	+0.698	-	-	-	-0.14	1	5848
7602	188512	G8 IV	+0.86	+0.49	+0.490	-	+0.368	+1.243	-	2	5877,5903
7633	189276	K5 II-III	+1.60	+1.93	-	-	-	-	-	2	5877,5903
7635	189319	K5 III	+1.57	+1.93	+0.929	-	-	-	-	1	5800
7685	190940	K3 III	+1.33	+1.52	+0.650	-	-	-	-	1	5878
7689	191026	KO IV	+0.86	+0.57	+0.452	-	-	-	-	1	5878
7759	193092	K4 II	+1.64	+1.86	-	-	-	+1.336	-	1	5772
7841	195506	K2 III	+1.14	+1.09	+0.624	-	-	-	-	1	5870
7896	196755	G5 IV	+0.68	+0.23	-	-	-	+1.294	-	2	5734,5748
7957	198149	KO IV	+0.92	+0.61	+0.485	-	-	-	-	1	5772
8089	201251	K4 II	+1.57	+1.77	+0.820	-	+0.365	+1.277	-	2	5744,5869
8115	202109	G8 II	+1.00	+0.76	+0.480	-	-	-	-	1	5870
8173	203504	K1 III	+1.11	+1.05	+0.540	-	-	+1.503	-	3	5744,5869,5869
8228	204771	KO III	+0.97	+0.80	-	-	+0.376	+1.346	-	1	5773
8252	205435	G8 III	+0.89	+0.56	+0.477	-	+0.387	+1.372	-	2	5877,5903
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	+0.401	+1.362	-	1	5877

8313	206859	G5 Ib	+1.18	+0.99	+0.567	-	-	-	-	1	5773
8321	207089	KO Ib	+1.41	+1.35	+0.691	-	-	+1.489	-	1	5898
8414	209750	G2 Ib	+0.97	+0.77	+0.470	-	-	-	-	1	5872
8424	209945	K5 III	-	-	-	-	-	-	-	1	5898
8426	209960	K4 III	+1.41	+1.78	+0.773	-	-	-	-	1	5898
8498	211388	K3 II-III	+1.46	+1.62	+0.720	-	-	-	-	1	5773
8538	212496	G9 III	+1.02	+0.78	+0.548	-	+0.357	+1.271	-	2	5774,5884
8551	212943	KO III-IV	+1.06	+0.89	+0.564	-	+0.360	+1.243	-	2	5774,5884
8632	214868	K3 III	+1.33	+1.36	+0.683	-	-	-	-	3	5774,5774,5884
8649	215167	K4 III	+1.36	+1.56	+0.720	-	-	+1.256	-	1	5853
-	215549	K1 III-IV	+0.95	+0.66	-	-	+0.415	+1.235	-	2	5791,5854
8684	216131	G9 III	+0.94	+0.68	+0.473	-	+0.364	+1.340	-	2	5907,6051
8694	216228	K1 III	+1.05	+0.90	+0.510	-	+0.376	+1.354	-	1	5872
8726	216946	K5 Ib	+1.77	+1.97	+1.045	-	-	-	-	2	5790,5853
8804	218452	K5 III	+1.41	+1.72	+0.750	-	-	-	-	2	5790,5853
8832	219134	K3 V	+1.00	+0.89	+0.529	-	-	-	-	3	5777,5777,5886
8852	219615	G8 III	+0.91	+0.58	+0.506	-	+0.348	+1.255	-0.60	2	5778,5887
8860	219734	M2 III	+1.67	+1.97	-	-	-	-	-	3	5791,5854,5854
8874	219945	KO III	+1.03	+0.82	-	-	+0.383	+1.305	-	6	5776,5791,5854, 5854,5885,5885
8875	219962	K2 III	+1.13	+1.07	-	-	-	+1.347	-	2	5791,5854
8916	220954	K1 III	+1.08	+1.01	+0.504	-	+0.412	+1.376	-	2	5907,6051
8924	221148	K3 III	+1.08	+1.14	-	-	-	-	-	2	5791,5854
-	221170	G2 IV	+1.02	+0.59	-	-	-	-	-2.5	6	5792,5792,5793, 5855,5855,5856
8930	221345	KO III	+1.03	+0.88	+0.552	-	+0.356	+1.253	-	2	5777,5886
8974	222404	K1 IV	+1.03	+0.95	+0.510	-	+0.399	+1.386	-	1	5843
9103	225212	K3 Ib	-	-	+0.806	-	-	-	-	2	5794,5857

Comments to Table 1

HD	3690	(B-V) has been transformed from (P-V); Eggen [35]
HD	38751	(R-I) has been transformed from six-colour (R-I)$_6$; Wallerstein and Helfer [28]
HD	50281	UBV data from Johnson and Knuckles [36]
HD	50282	Spectral type has been estimated by the aut
HD	166208	(R-I) has been transformed from six-colour (R-I)$_6$; Wallerstein and Helfer [28]
HD	168322	[Fe/H] from Greenstein and Keenan [34] corrected with -0.5 (see Section 7)
HD	188056	(R-I) has been transformed from six-colour (R-I)$_6$; Wallerstein and Helfer [28]
HD	215167	UBV data from Johnson and Knuckles [36]
HD	219615	[Fe/H] from Greenstein and Keenan [34] corrected with -0.5 (see Section 7)
HD	221170	All data from Wallerstein and Helfer [28]
HD	225212	(R-I) has been transformed from six-colour (R-I)$_6$; Stebbins and Whitford [37]

Table 2

Dispersion table

4340 A	166 A/mm
4000	122
3900	110
3800	100
3700	90
3600	80

Table 3

Lines that have been identified in the spectra (cf. Section 5).

Line no.		Measured w.l.	Identification	
6	X	3968.7	3970.1	H_ε
			3968.5	CaII
7		3943.6	3944.0	AlI
8	X	3933.0	3933.7	CaII
9		3921.0	3922.9	FeI
			3920.3	FeI
10	X	3905.8	3906.5	FeI
			3905.5	SiI
11		3895-99	3899.7	FeI
			3895.7	FeI
			3894.0	CrI
12		3887.3	3889.1	H_δ
			3888.5	FeI
			3887.0	FeI
			3886.3	FeI
13		3878-82	3879-83	CN
			3878.7	FeI
14		3869-72	3872.5	FeI
			3868-72	CN
15		3859.1	3859.9	FeI
16		3849.3	3850.0	FeI
17		3839.8	3841.1	FeI
			3840.4	FeI
			3838.3	MgI
18	X	3832.9	3832.3	MgI
19	X	3825.8	3825.9	FeI
20	X	3820.3	3820.4	FeI
21		3814.7	3815.8	FeI
			3813.5	VI
22		3806.9	3807.5	FeI
			3807.1	NiI
			3806.7	FeI
23		3798.8	3798.5	FeI
24		3793.8	3795.0	FeI
			3793.6	NiI
25		3788.1	3787.9	FeI
26		3777.0	3777.5	FeI
			3776.6	YII

27		3763.3	3763.8	FeI
28	X	3758.3	3758.2	FeI
			3759.3	TiII
29		3749.0	3749.5	FeI
			3749.1	NiI
			3748.3	FeI
30		3734.9	3734.9	FeI
31		3727.6	3727.6	FeI
32	X	3720.3	3719.9	FeI
33		3705-09	3709.3	FeI
			3706.0	CaII
			3705.6	FeI
34		3695.2	3693.9	NiI
35		3687.1	3687.5	FeI
36		3679.1	3679.9	FeI
			3679.0	FeI
37		3669.2	3669.5	FeI
			3669.2	NiI
38		3663.2	3662-64	Several lines TiII, CrI,FeI,NiI
39		3656.0	3656.3	CrI
40	X	3647.5	3647.8	FeI
			3647.7	CoI
			3647.4	FeI
41		3631.3	3631.7	CrII
			3631.5	FeI
			3631.0	CaI
42	X	3619.0	3619.4	NiI
			3618.8	FeI
43		3955		
44		3914		
45		3892		
46		3884		
47		3875		
48		3864		
49		3845		
50		3807		
51		3782		
52		3742		

An X indicates that the line was used in the computation preliminary Hartmann coefficients. The measured wavelengths been computed from the improved Hartmann coefficients.

Table 4

Key to groups

Group	No.of spectra	Characteristics	MK class	(B-V)	(U-B)	(R-I)	M_V	C	C"	[Fe/H]
1	15	G5-K5 I,II	+	+	+	+				
2	98	G5-M2 II-III, III, III-IV	+	+	+	+				
3	67	G8-K2 II-III, III, III-IV	+	+	+	+		+	+	+
4	41	K2-K5 II-III, III	+	+	+	+				
5	31	G5-K4 IV, V	+	+	+	+				
6	42	G5-G9 III-V					+			
7	46	K0-K1 III-V					+			
8	40	K2-K4 III-V					+			
9	151	G2-M2 I-V	+	+	+	+	+			
11	21	G5-K5 I,II	+	+	+	+				
12	135	G5-M2 II-III, III, III-IV	+	+	+	+				
13	91	G8-K2 II-III, III, III-IV	+	+	+	+		+	+	+
14	58	K2-K5 II-III, III	+	+	+	+				
15	31	G5-K4 IV-V	+	+	+	+				
16	50	G5-G9 III-V					+			
17	59	K0-K1 III-V					+			
18	57	K2-K4 III-V					+			
19	194	G2-M2 I-V	+	+	+	+	+			

A "+" signifies that correlation coefficients have been computed between all line-ratios and the the spectral parameter for the group in question (Section 7). Groups 1 - 9 correspond to CONT I, groups 11 - 19 to CONT II.

Table 5a

MK spectral class

Group	n1	Two best line ratios	n2	n3	ε
1	15	12/18 9/49	14 15	1 1	0.053 0.073
2	98	9/14 12/14	92 93	5 2	0.113 0.112
3	67	14/31 18/52	64 62	5 5	0.132 0.126
4	41	9/14 7/48	39 40	2 1	0.086 0.089
5	31	6/9 8/52	31 31	3 1	0.108 0.113
9	151	6/9 8/52	141 138	2 2	0.217 0.238
11	21	9/49 12/16	21 21	2 1	0.104 0.119
12	135	11/14 11/16	132 131	5 5	0.136 0.141
13	91	14/31 15/27	87 89	4 5	0.135 0.141
14	58	9/14 9/48	56 57	2 2	0.069 0.072
15	31	6/52 8/52	31 31	2 2	0.105 0.099
19	194	18/52 14/31	185 182	4 4	0.195 0.210

Table 5b

(U-B)

Group	n1	Two best line ratios	n2	n3	ε
1	13	12/14 12/16	13 13	1 1	0.070 0.096
2	89	9/14 12/14	83 84	4 3	0.175 0.162
3	65	12/14 17/27	62 61	2 3	0.195 0.193
4	36	12/14 11/16	33 36	2 1	0.112 0.165
5	29	15/17 15/18	28 28	0 1	0.144 0.131
9	137	9/17 9/18	128 126	1 2	0.384 0.319
11	19	6/12 14/20	19 18	2 1	0.090 0.110
12	125	9/14 14/31	119 118	5 3	0.176 0.207
13	87	17/27 14/31	84 84	3 3	0.187 0.206
14	53	14/27 14/23	52 52	2 2	0.165 0.170
15	29	15/17 15/18	28 28	1 1	0.149 0.141
19	180	17/27 18/27	173 171	3 1	0.380 0.403

Table 5c

(B-V)

Group	n1	Two best line ratios	n2	n3	ε
1	13	11/48	13	1	0.065
		12/14	13	1	0.058
2	93	9/14	87	4	0.074
		12/14	88	4	0.080
3	66	9/14	61	3	0.089
		12/14	63	3	0.081
4	39	9/14	37	1	0.064
		9/48	38	0	0.073
5	29	17/52	28	2	0.075
		6/47	29	1	0.078
9	142	9/17	132	2	0.170
		9/18	130	2	0.164
11	19	14/20	18	1	0.084
		6/12	19	2	0.057
12	129	9/14	123	6	0.080
		9/16	123	5	0.099
13	89	9/14	84	2	0.103
		14/31	85	3	0.106
14	56	7/14	54	3	0.081
		9/48	55	3	0.088
15	29	6/52	29	1	0.079
		18/52	28	1	0.078
19	184	9/17	174	2	0.217
		18/25	176	2	0.222

Table 5d

(R-I)

Group	n1	Two best line ratios	n2	n3	ε
1	13	9/48	13	0	0.045
		11/48	13	1	0.034
2	60	11/14	57	1	0.059
		12/14	57	2	0.042
3	48	12/13	47	2	0.043
		12/14	46	2	0.034
4	24	7/14	23	1	0.038
		12/14	23	0	0.053
5	22	9/12	22	0	0.040
		22/47	22	0	0.040
9	97	9/15	92	2	0.123
		47/49	91	1	0.117
11	18	9/48	18	1	0.051
		11/48	18	1	0.054
12	94	9/16	89	2	0.060
		11/14	92	1	0.054
13	68	11/14	66	2	0.048
		11/51	65	1	0.048
14	41	7/14	40	2	0.034
		12/14	40	1	0.052
15	22	9/12	22	0	0.041
		10/52	22	0	0.040
19	135	9/49	131	3	0.150
		13/14	135	6	0.126

Table 5e

M_V

Group	n1	Two best line ratios	n2	n3	ε
6	34	13/17 19/48	31 27	0 0	0.64 0.52
7	32	12/50 25/27	32 31	0 2	1.82 1.99
8	17	8/18 44/45	17 17	1 1	1.50 1.19
9	93	11/43 44/45	89 85	2 0	3.26 3.41
16	41	12/48 16/18	38 34	0 0	0.74 0.78
17	41	10/13 6/10	41 41	1 1	1.35 1.25
18	24	12/28 46/47	22 21	1 2	1.61 1.31
19	124	10/25 10/26	122 124	0 1	2.91 3.12

Table 5f

C

Group	n1	Two best line ratios	n2	n3	ε
3	47	14/49 8/17	45 40	3 1	0.015 0.015
13	67	8/18 28/50	60 63	2 3	0.015 0.020

Table 5g

C"

Group	n1	Two best line ratios	n2	n3	ε
3	64	13/50 6/50	64 56	4 3	0.042 0.043
13	87	8/50 8/16	78 77	4 2	0.041 0.053

Table 5h

[Fe/H]

Group	n1	Two best line ratios	n2	n3	ε
3	13	8/18 8/23	12 12	0 0	0.137 0.114
13	18	8/50 14/50	17 18	0 0	0.118 0.158

Table 6a

MK spectral class

Group	n	Line ratio combination	ε_{ext}	ε_{int}	n_{st}	n_{sp}
1	14	5.094 +1.485(12/18) ±0.063 ±0.086	0.127 (0.053)*	0.057	4	8
2	89	6.267 +0.727(9/14) −0.469(14/25) ±0.135 ±0.071 ±0.071	0.091	0.066	23	58
5	31	6.634 −0.086(8/ 9) −0.121(8/52) ±0.059 ±0.030 ±0.023	0.106	0.073	11	23
9	119	7.214 −0.329(14/47) −0.274(18/31) ±0.070 ±0.054 ±0.023	0.129	0.092	33	74
11	21	5.227 +0.359(9/49) +0.774(12/13) ±0.095 ±0.107 ±0.199	0.106 (0.077)*	0.064	4	9
12	128	6.269 +0.586(9/14) −0.347(14/27) ±0.104 ±0.079 ±0.049	0.104	0.059	35	82
15	29	6.726 −0.088(8/31) −0.183(18/52) ±0.073 ±0.021 ±0.045	0.102	0.041	9	19
19	173	6.942 −0.194(17/31) −0.188(18/52) ±0.037 ±0.029 ±0.026	0.134	0.088	47	107

The following code is used: G5 = 5.5, K0 = 6.0, K5 = 6.5 and M0 = 6.6.

* When excluding HR 8313 that falls far off the regression line in Figs. 2a and 2e. The linear combinations were computed without HR 8313.

Table 6b

(R-I)

Group	n	Line ratio combination	ε_{ext}	ε_{int}	n_{st}	n_{sp}
1	13	0.144 +0.625(9/48) ±0.037 ±0.040	0.045	0.016	4	9
2	57	0.137 +0.639(12/14) ±0.023 ±0.032	0.044	0.033	18	43
5	22	0.626 −0.179(22/47) ±0.047 ±0.048	0.040	0.022	8	17
9	88	−0.012 +0.484(9/15) +0.291(47/49) ±0.074 ±0.107 ±0.101	0.096	0.037	25	59
11	18	0.249 +0.323(9/49) +0.199(12/48) ±0.033 ±0.086 ±0.076	0.049	0.030	4	9
12	91	0.580 +0.720(11/14) −0.115(14/27) ±0.045 ±0.061 ±0.024	0.046	0.031	25	59
15	21	0.314 −0.132(10/52) +0.175(15/25) ±0.081 ±0.032 ±0.051	0.032	0.017	7	15
19	131	−0.304 +0.399(9/15) +0.810(13/14) ±0.082 ±0.102 ±0.121	0.098	0.052	38	85

Table 6c

M_V

Group	n	Line ratio combination	ε_{ext}	ε_{int}	n_{st}	n_{sp}
6	27	-0.283 +1.402(19/48) ±0.264 ±0.140	0.52	0.15	8	19
7	29	-15.876 +4.368(10/47) +3.328(12/50) ± 3.157 ±2.923 ±1.782 + 7.259(20/25) ± 2.255	1.29	0.87	8	16
8	14	-6.445 -7.016(44/45) +14.929(46/47) ±3.826 ±2.079 ± 2.702	0.91	0.77	4	9
16	38	0.855 +1.312(12/48) ±0.207 ±0.185	0.74	0.16	11	28
17	38	-1.466 -0.980(6/10) +3.567(20/50) ±2.389 ±0.183 ±0.743	1.16	0.91	13	26
18	19	-16.545 +11.020(12/28) +10.712(46/47) ± 1.406 ± 2.812 ± 2.136	0.98	0.73	5	11

Table 6d

C, C'' and [Fe/H]

Group	n	Line ratio combination	ε_{ext}	ε_{int}	n_{st}	n_{sp}
3	45	C = 0.504 -0.092(14/49) ±0.021 ±0.014	0.016	0.009	12	35
	64	C'' = 1.605 -0.162(13/50) ±0.040 ±0.022	0.045	0.023	20	52
	12	[Fe/H] = 1.831 -1.001(8/23) ±0.294 ±0.126	0.114	0.076	4	8
13	60	C = 0.548 -0.115(8/18) ±0.023 ±0.015	0.016	0.009	16	41
	78	C'' = 1.554 -0.062(8/50) ±0.023 ±0.006	0.043	0.023	22	53
	17	[Fe/H] = 0.624 -0.255(8/50) ±0.124 ±0.029	0.118	0.049	5	10

Table 7

Comparison between $[Fe/H]_{AB}$ and $[Fe/H]_{pe}$

Group	$[Fe/H]_{AB}$ =	n	s.d.
3	0.715 - 0.334(6/50)	56	0.185
	2.592 - 1.858(8/18)	55	0.173
	1.433 - 1.183(8/19)	53	0.125
	1.831 - 1.001(8/23)	55	0.152
	0.979 - 0.317(8/26)	55	0.217
	1.767 - 1.474(13/22)	64	0.195
	-1.110 + 0.505(43/44)	57	0.284
13	2.185 - 1.790(6/18)	76	0.178
	0.791 - 0.262(8/26)	78	0.246
	0.624 - 0.255(8/50)	78	0.158
	1.257 - 1.307(13/49)	85	0.182
	0.721 - 0.491(14/50)	86	0.175
	1.231 - 0.651(18/50)	82	0.220
	3.203 - 3.031(20/21)	74	0.276

Group no., cf. Table 4. Line no., cf. Table 3. The results for (group 3, line ratio (8/23)) and (group 13, line ratio (8/50)) are shown graphically in Figures 8a and 8b .

Figure captions.

Fig. 1. A spectral recording. The fourty-seven points, where the depth has been measured, are indicated by the line - numbers, given in Table 3. The two straight-line continua, CONT I and CONT II are discussed in Section 6.

Fig. 2a. The spectral type Sp_{AB}, computed as $Sp_{AB} = 5.094 + 1.485\times(12/18)$. The code in figures 2a to 2h is G0 = 5.0, G5 = 5.5, K0 = 6.0, K5 = 6.5, M0 = 6.6, M2 = 6.8 etc. Throughout the figures, the index "AB" refers to a spectral parameter, determined by the present line-ratio method by means of the Abastumani spectra. This figure contains 14 spectra and $\varepsilon_{ext} = 0.127$ (spectral class).

Fig. 2b. $Sp_{AB} = 6.267 + 0.727\times(9/14) - 0.469\times(14/25)$; 89 spectra; $\varepsilon_{ext} = 0.091$.

Fig. 2c. $Sp_{AB} = 6.634 - 0.086\times(8/9) - 0.121\times(8/52)$; 31 spectra; $\varepsilon_{ext} = 0.106$.

Fig. 2d. $Sp_{AB} = 7.214 - 0.329\times(14/47) - 0.274\ (18/31)$; 119 spectra; $\varepsilon_{ext} = 0.129$. The luminosity classes have been indicated with different signatures.

Fig. 2e. $Sp_{AB} = 5.227 + 0.359\times(9/49) + 0.774(12/13)$; 21 spectra; $\varepsilon_{ext} = 0.106$.

Fig. 2f. $Sp_{AB} = 6.269 + 0.586\times(9/14) - 0.347(14/27)$; 128 spectra; $\varepsilon_{ext} = 0.104$.

Fig. 2g. $Sp_{AB} = 6.726 - 0.088(8/31) - 0.183(18/52)$; 29 spectra; $\varepsilon_{ext} = 0.102$.

Fig. 2h. $Sp_{AB} = 6.942 - 0.194\times(17/31) - 0.188\times(18/52)$; 173 spectra; $\varepsilon_{ext} = 0.134$; The luminosity classes have been indicated with different signatures.

Fig. 3a. $(R-I)_{AB} = 0.144 + 0.625\times(9/48)$; 13 spectra; $\varepsilon_{ext} = 0\overset{m}{.}045$.

Fig. 3b. $(R-I)_{AB} = 0.137 + 0.639\times(12/14)$; 57 spectra; $\varepsilon_{ext} = 0\overset{m}{.}044$.

Fig. 3c. $(R-I)_{AB} = 0.626 - 0.179\times(22/47)$; 22 spectra; $\varepsilon_{ext} = 0\overset{m}{.}040$.

Fig. 3d. $(R-I)_{AB} = 0.249 + 0.323\times(9/49) + 0.199\times(12/48)$; 18 spectra; $\varepsilon_{ext} = 0\overset{m}{.}049$.

Fig. 3e. $(R-I)_{AB} = 0.580 + 0.720\times(11/14) - 0.115\times(14/27)$; 91 spectra; $\varepsilon_{ext} = 0\overset{m}{.}046$.

Fig. 3f. $(R-I)_{AB} = 0.314 - 0.132\times(10/52) + 0.175\times(15/25)$; 21 spectra; $\varepsilon_{ext} = 0\overset{m}{.}032$.

Fig. 4a. $M_V^{AB} = -0.283 + 1.402\times(19/48)$; 27 spectra; $\varepsilon_{ext} = 0\overset{m}{.}52$.

Fig. 4b. $M_V^{AB} = -15.876 + 4.368\times(10/47) + 3.328\times(12/50) + 7.259\times(20/25)$; 29 spectra; $\varepsilon_{ext} = 1\overset{m}{.}29$.

Fig. 4c. $M_V^{AB} = -6.445 - 7.016\times(44/45) + 14.929\times(46/47)$; 14 spectra; $\varepsilon_{ext} = 0\overset{m}{.}91$.

Fig. 4d. $M_V^{AB} = 0.855 + 1.312\times(12/48)$; 38 spectra; $\varepsilon_{ext} = 0\overset{m}{.}74$.

Fig. 4e. $M_V^{AB} = -1.466 - 0.980\times(6/10) + 3.567\times(20/50)$; 38 spectra; $\varepsilon_{ext} = 1\overset{m}{.}16$.

Fig. 4f. $M_V^{AB} = -16.545 + 11.020\times(12/18) + 10.712\times(46/47)$; 19 spectra; $\varepsilon_{ext} = 0\overset{m}{.}98$;

Fig. 5. Spectra of stars of different luminosity classes. The break around 4000 A that is proportional to the angle subtended by CONT I and CONT II is largest in the supergiants.

Fig. 6a. $C_{AB} = 0.504 - 0.092\times(14/49)$; 45 spectra; $\varepsilon_{ext} = 0.016$.

Fig. 6b. $C''_{AB} = 1.605 - 0.162\times(13/50)$; 64 spectra; $\varepsilon_{ext} = 0.045$.

Fig. 6c. $C_{AB} = 0.548 - 0.115\times(8/18)$; 60 spectra; $\varepsilon_{ext} = 0.016$.

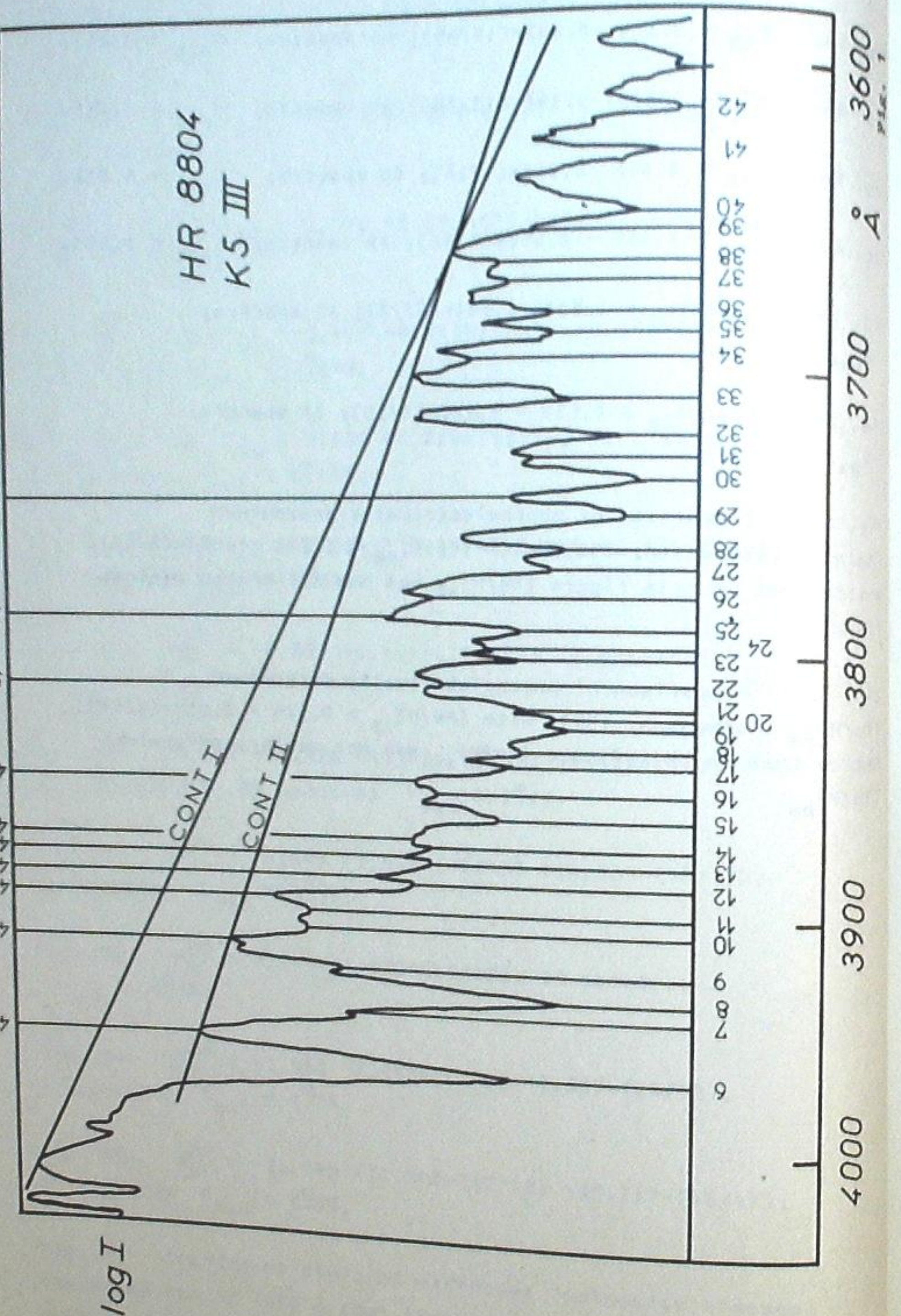
Fig. 6d. $C''_{AB} = 1.554 - 0.062\times(8/50)$; 78 spectra; $\varepsilon_{ext} = 0.043$.

Fig. 7a. $[Fe/H]_{AB} = 1.831 - 1.001\times(8/23)$; 12 spectra; $\varepsilon_{ext} = 0.114$.

Fig. 7b. $[Fe/H]_{AB} = 0.624 - 0.255\times(8/50)$; 17 spectra; $\varepsilon_{ext} = 0.118$.

Fig. 8a. Comparison of photoelectrically determined $[Fe/H]_{pe}$ (Rasmussen, 1969) with $[Fe/H]_{AB} = 1.831 - 1.001\times(8/23)$. Notice that in this figure $[Fe/H]_{AB}$ was not calibrated against $[Fe/H]_{pe}$.

Fig. 8b. Comparison of photoelectrically determined $[Fe/H]_{pe}$ (Rasmussen, 1969) with $[Fe/H]_{AB} = 0.624 - 0.255\times(8/50)$. Notice that in this figure $[Fe/H]_{AB}$ was not calibrated against $[Fe/H]_{pe}$.


HR 8804
K5 III
log I
CONT I
CONT II
Å
4000
3900
3800
3700
3600
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
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29
30
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49
50
51
52

Fig. 1

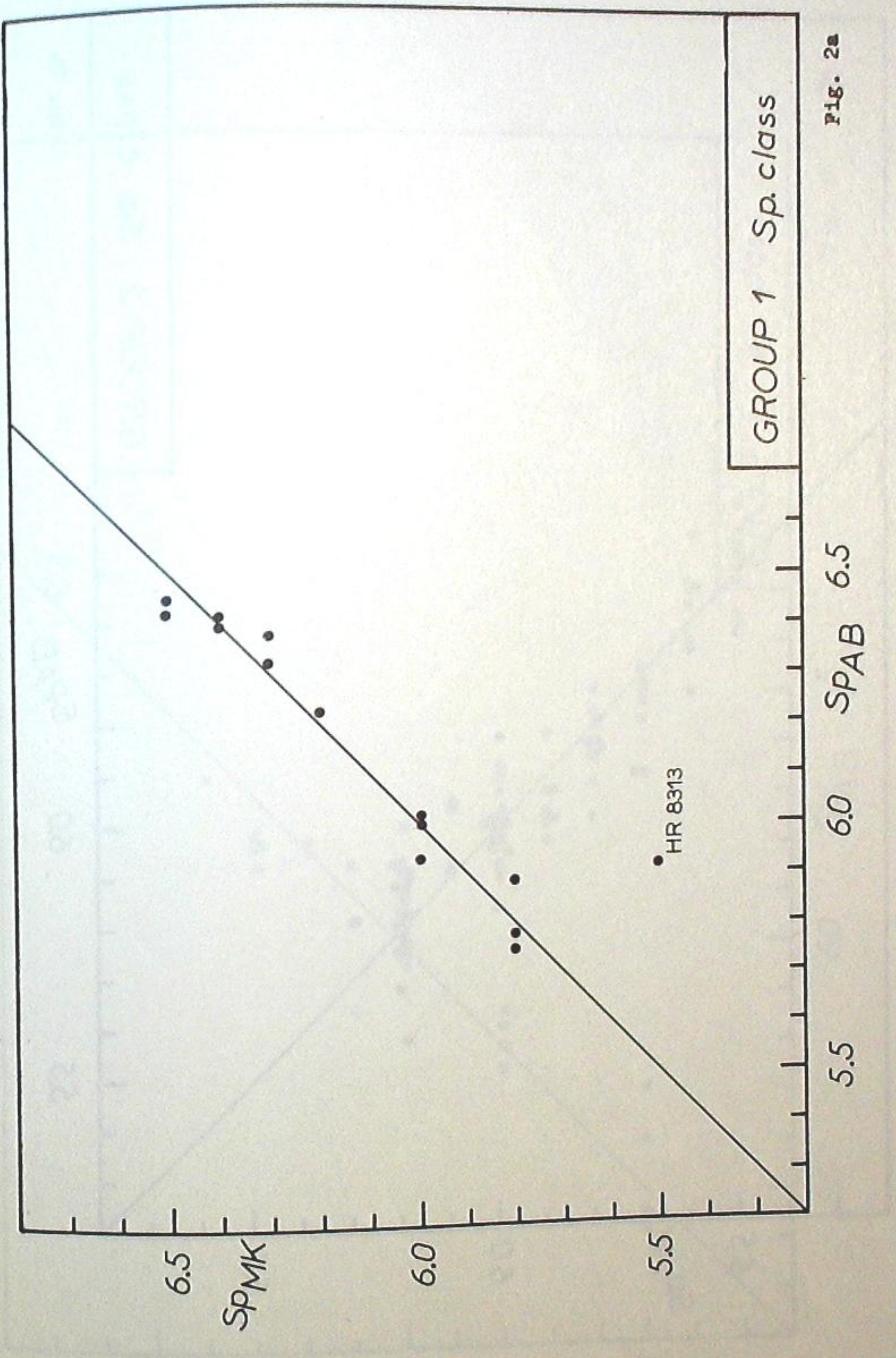

GROUP 1 Sp. class
SpAB
SpMK
5.5
6.0
6.5
5.5
6.0
6.5
HR 8313

Fig. 2a

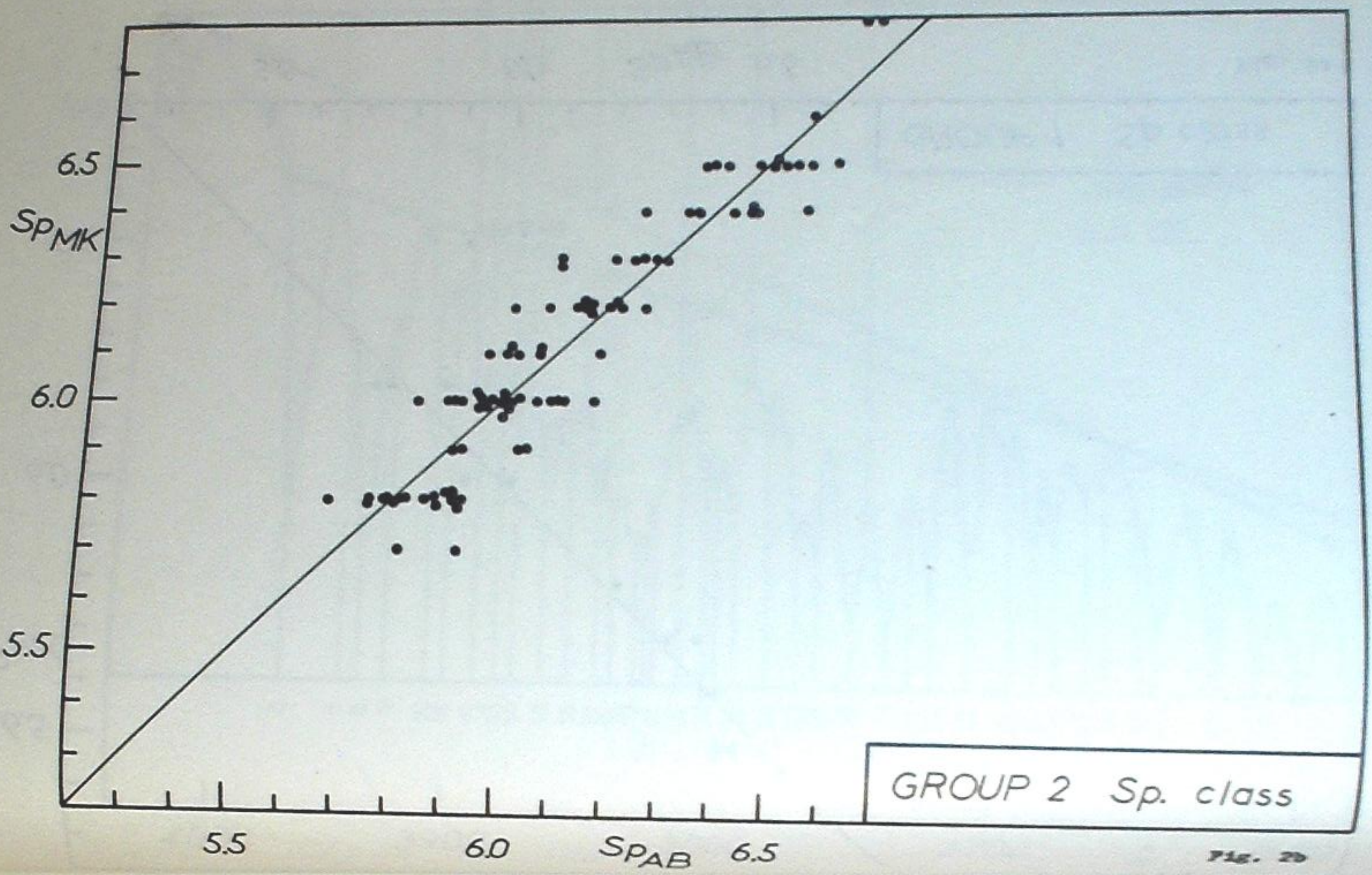

6.5
SpMK
6.0
5.5
5.5
6.0
SpAB
6.5
GROUP 2 Sp. class

Fig. 2b

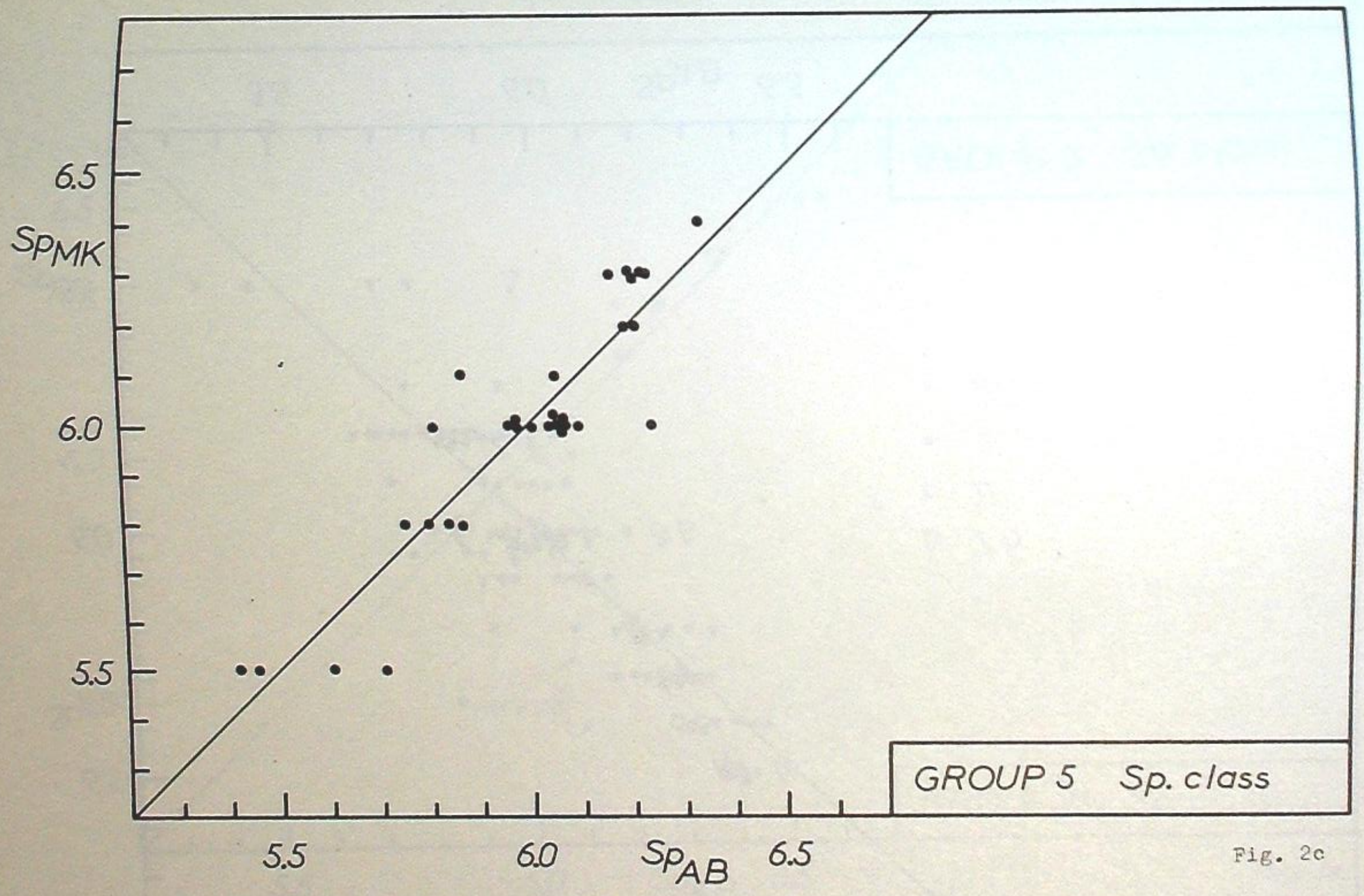

6.5
SpMK
6.0
5.5
5.5
6.0
SpAB
6.5
GROUP 5 Sp. class

Fig. 2c

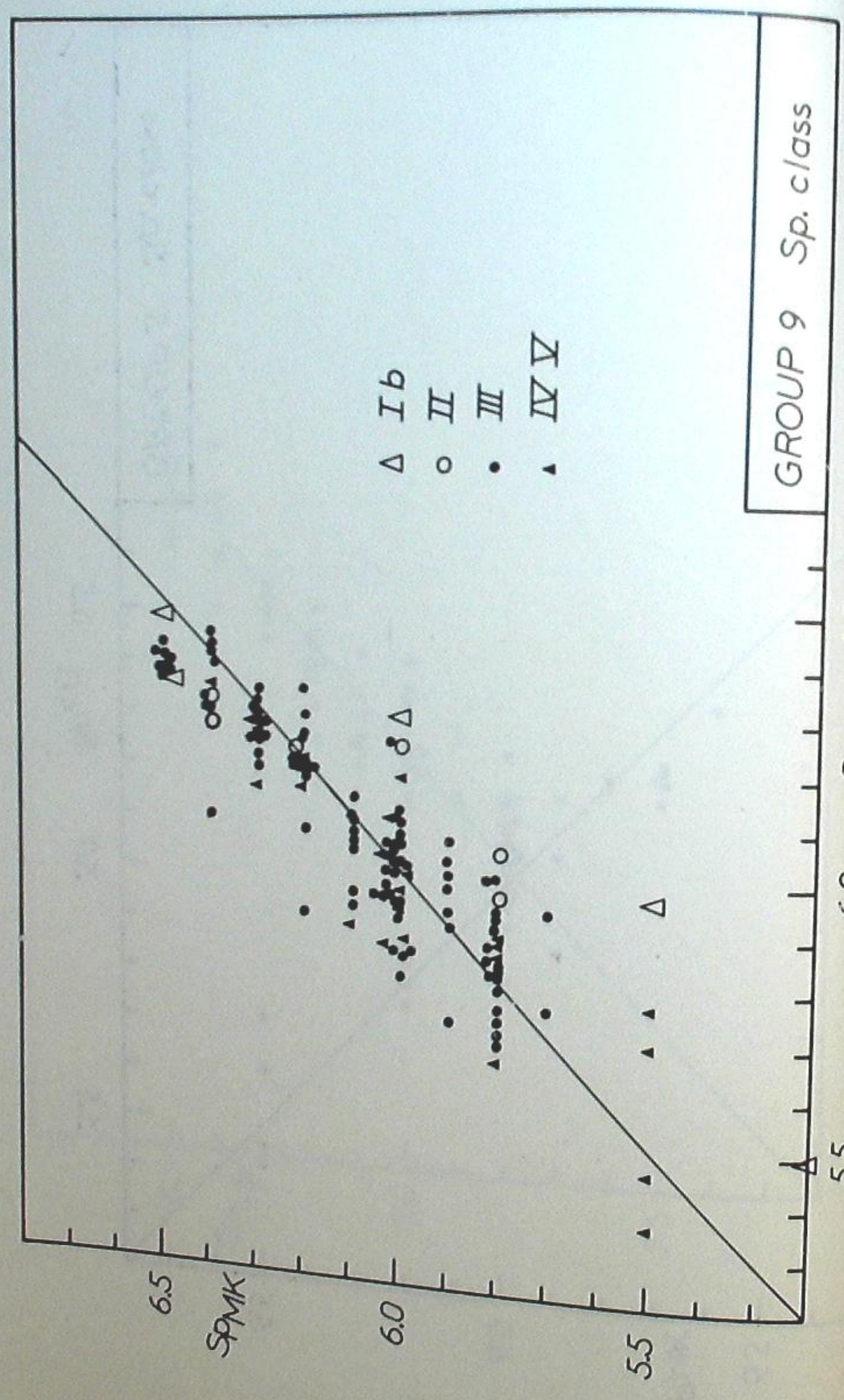

GROUP 9 Sp. class
Δ Ib
○ II
● III
▲ IV V
δ
SpMK
6.5
6.0
5.5
SpAB
5.5
6.0
6.5

Fig. 2d

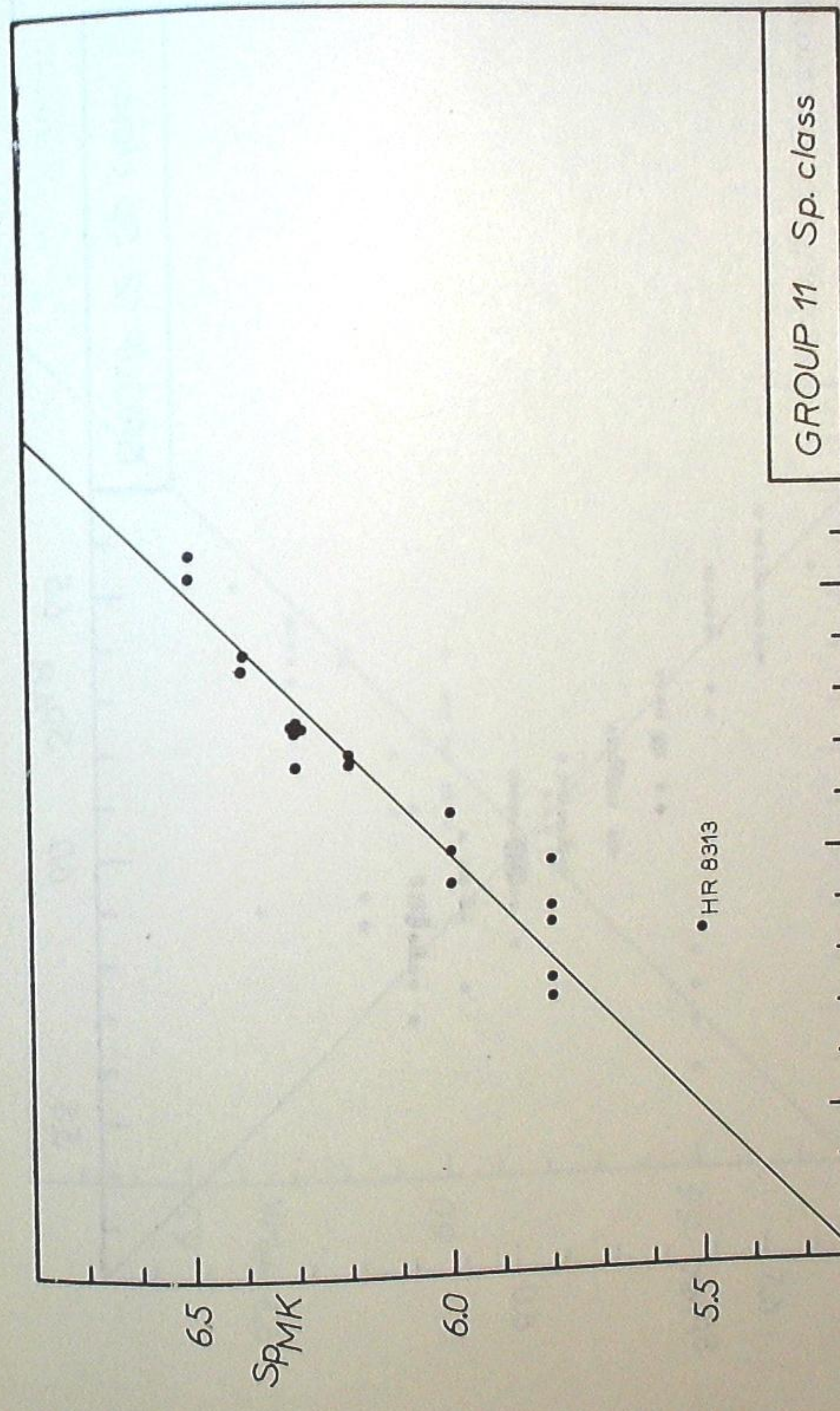

GROUP 11 Sp. class
HR 8313
SpMK
6.5
6.0
5.5
SpAB
5.5
6.0
6.5

Fig. 2e

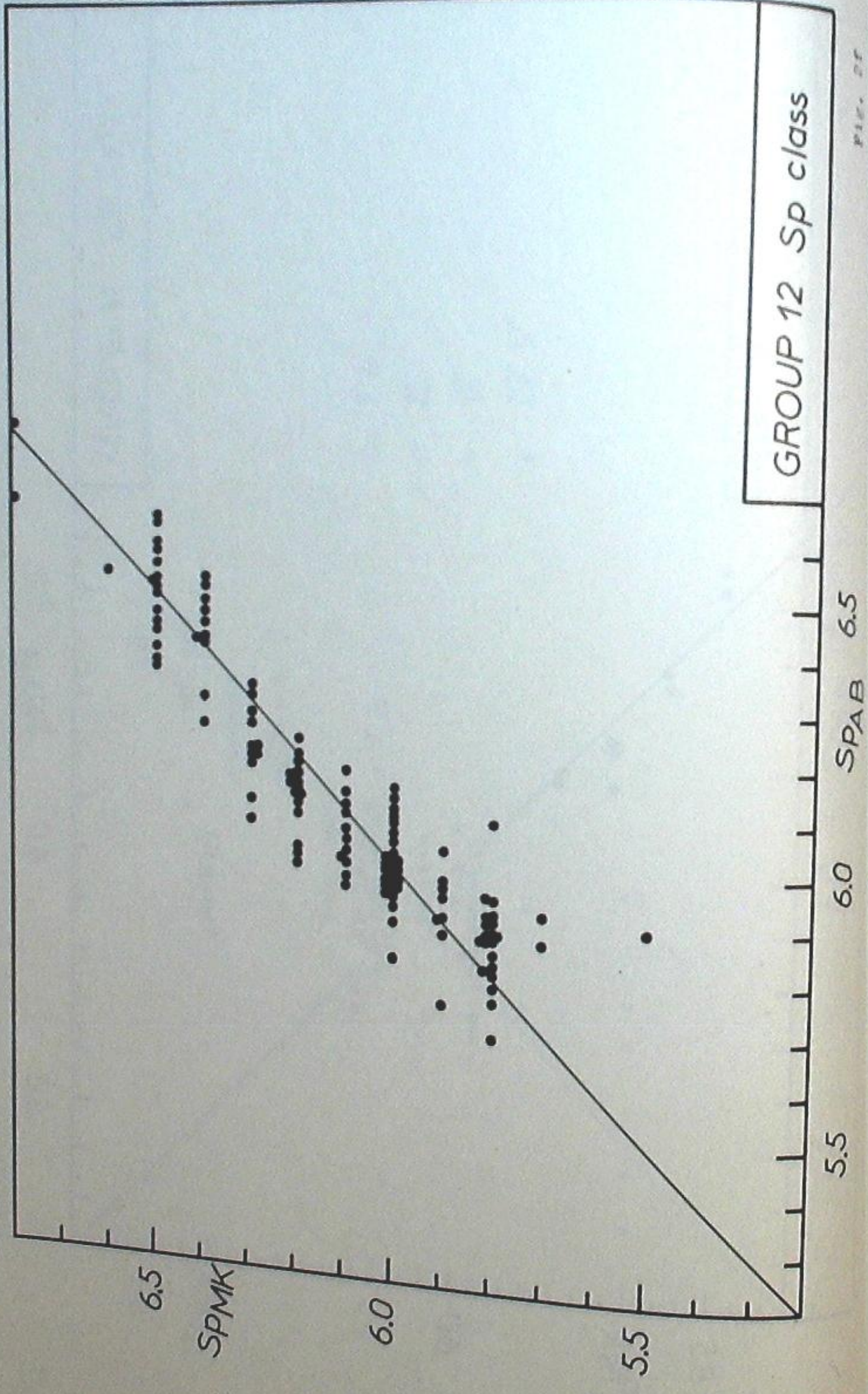

GROUP 12 Sp class
SPAB
SPMK
5.5
6.0
6.5
5.5
6.0
6.5

Fig. 2f

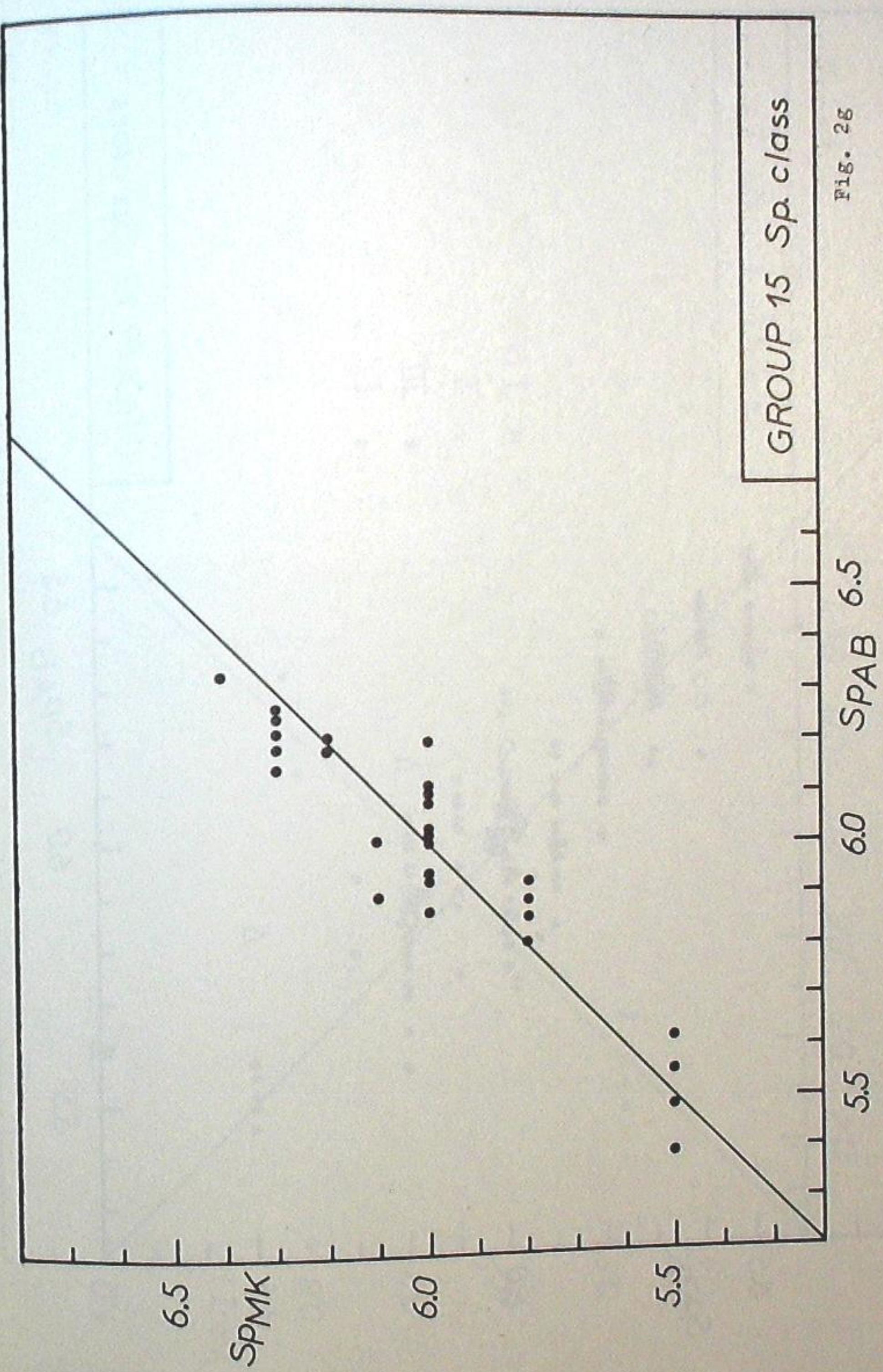

GROUP 15 Sp. class
SPAB
SPMK
5.5
6.0
6.5
5.5
6.0
6.5

Fig. 2g

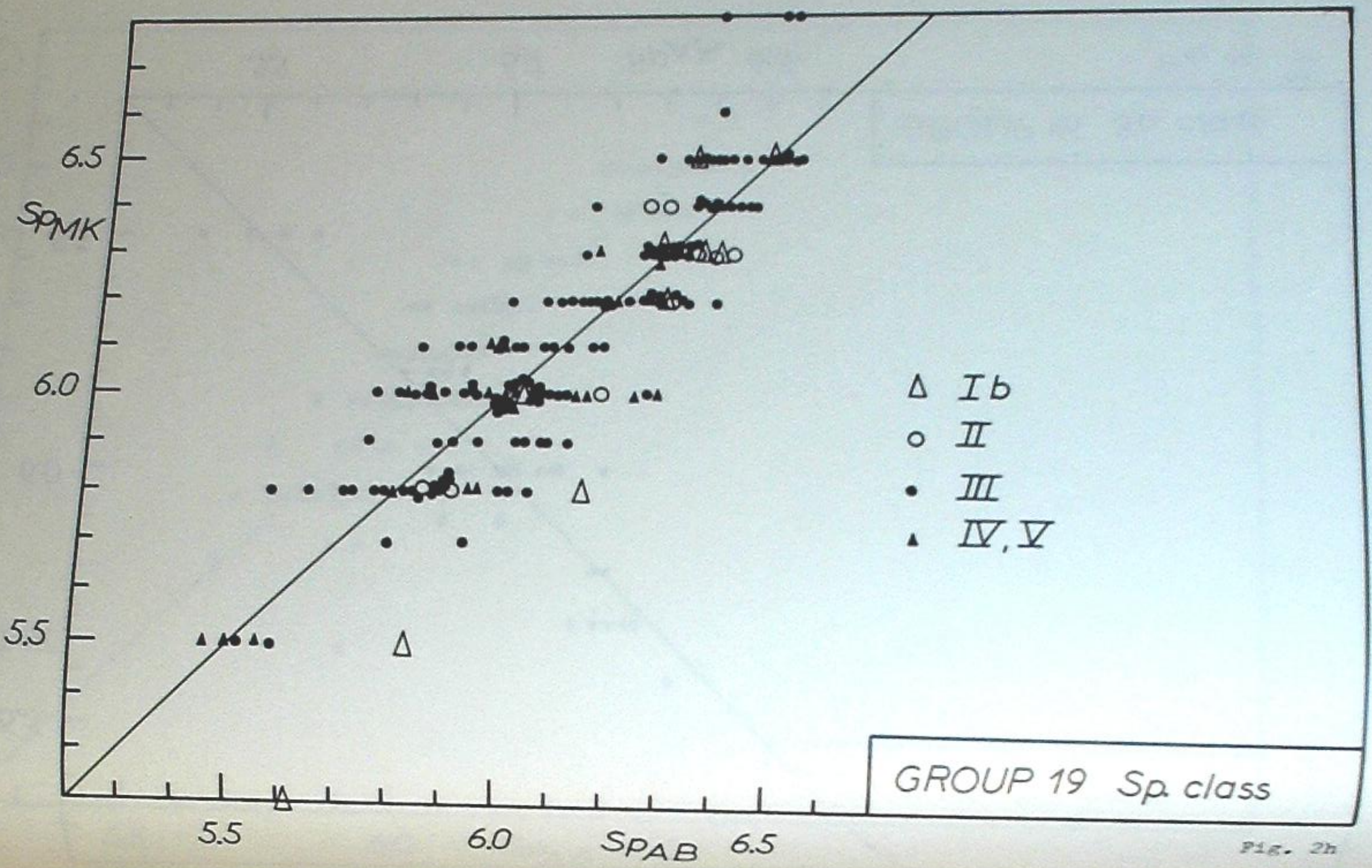

Sp_MK
6.5
6.0
5.5
Sp_AB
5.5
6.0
6.5
Δ Ib
○ II
● III
▲ IV,V
GROUP 19 Sp. class

Fig. 2h

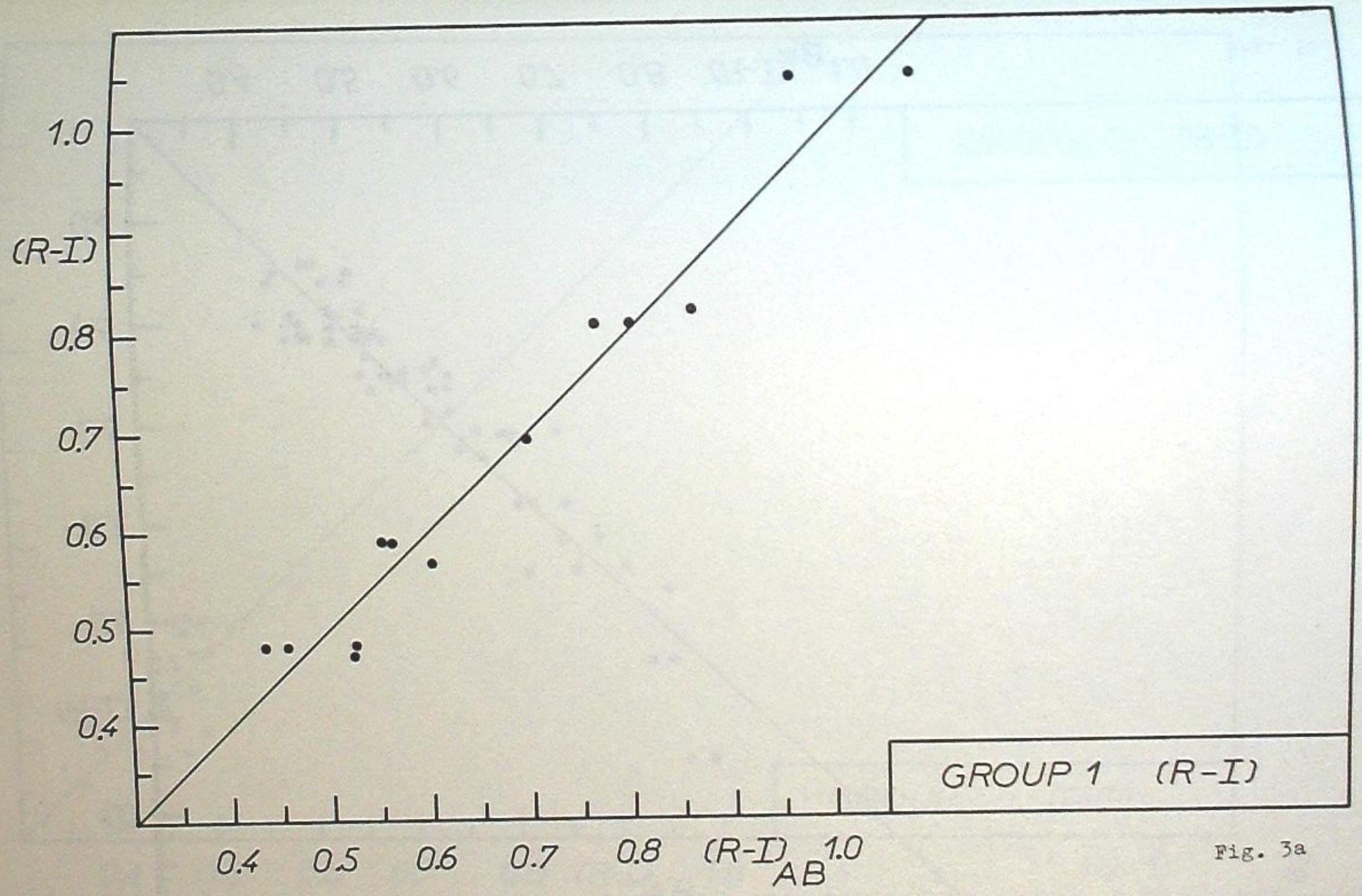

(R-I)
1.0
0.8
0.7
0.6
0.5
0.4
(R-I)_AB
0.4
0.5
0.6
0.7
0.8
1.0
GROUP 1 (R-I)

Fig. 3a

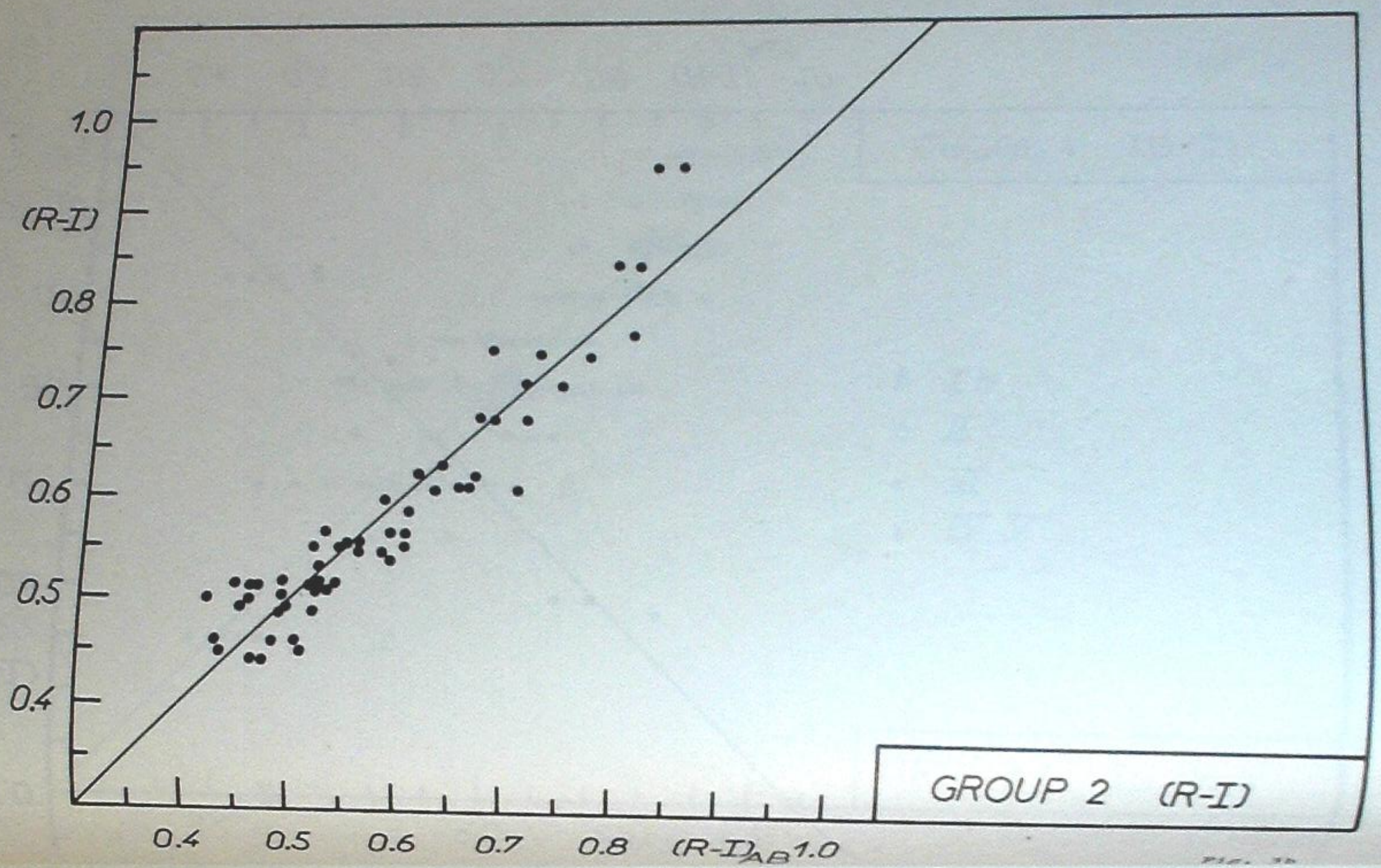

GROUP 2 (R-I)
(R-I)
1.0
0.8
0.7
0.6
0.5
0.4
$(R-I)_{AB}$
0.4
0.5
0.6
0.7
0.8
1.0

Fig. 3b

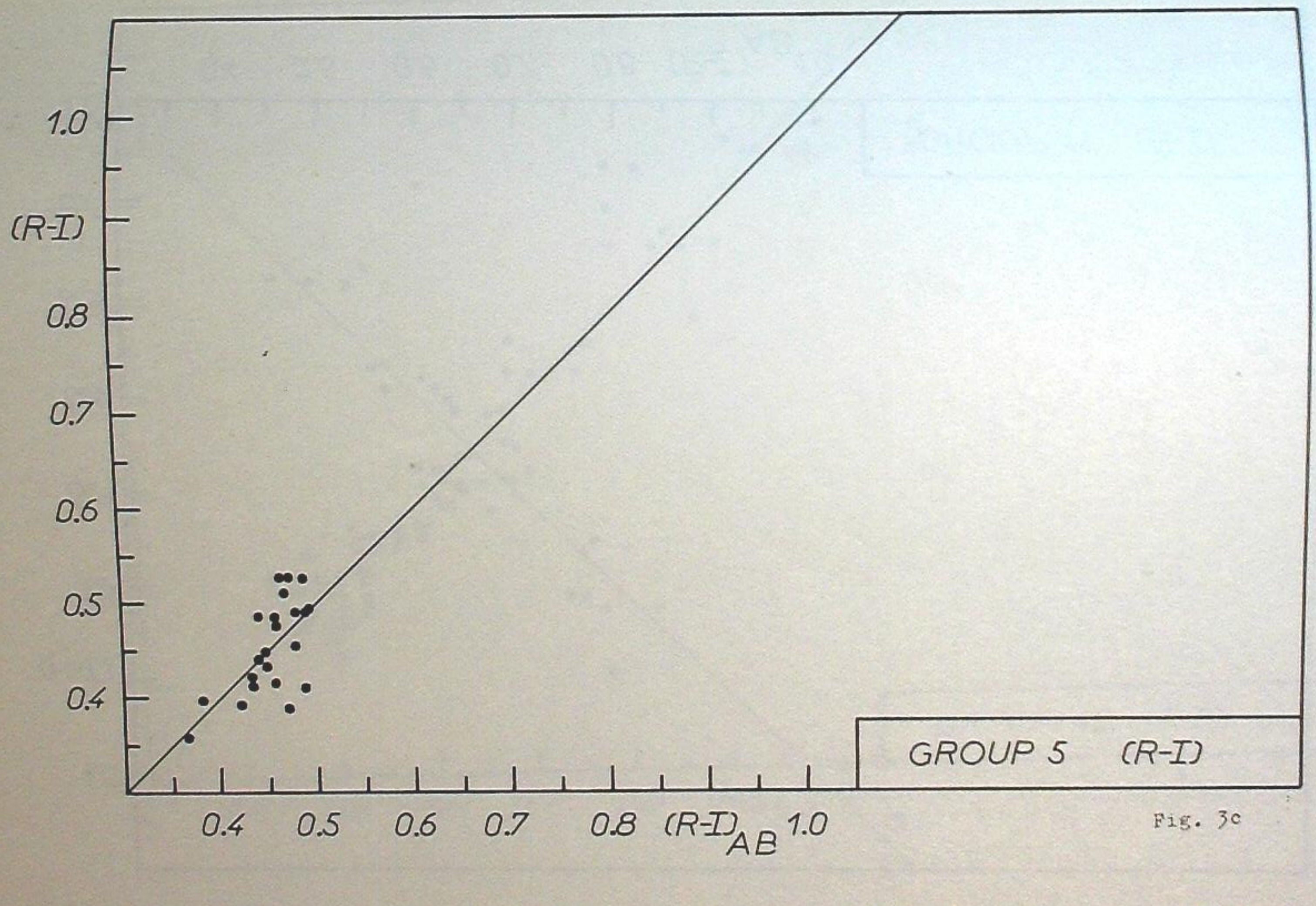

GROUP 5 (R-I)
(R-I)
1.0
0.8
0.7
0.6
0.5
0.4
$(R-I)_{AB}$
0.4
0.5
0.6
0.7
0.8
1.0

Fig. 3c

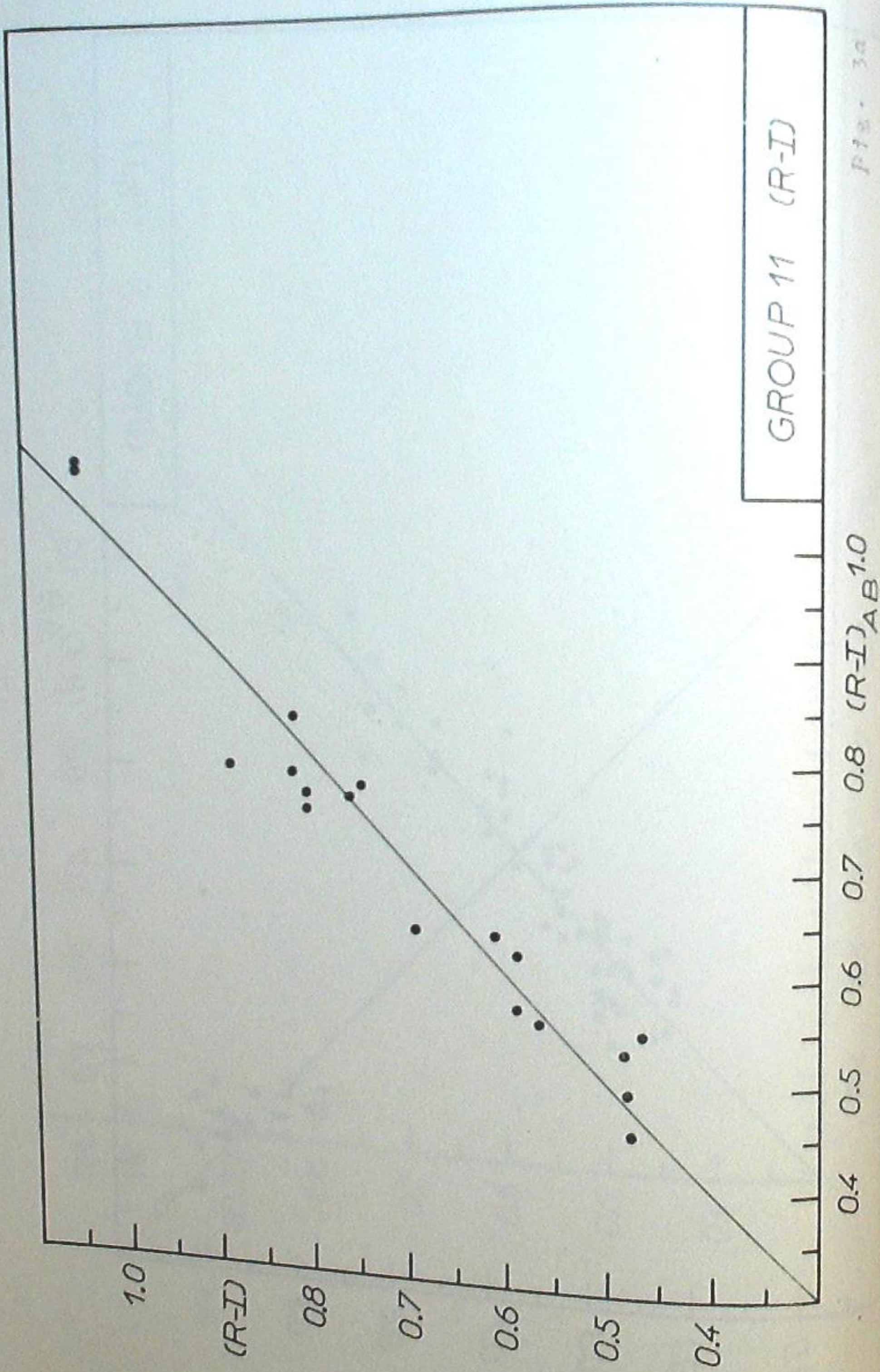

GROUP 11 (R-I)
0.4
0.5
0.6
0.7
0.8
$(R-I)_{AB}$
1.0
1.0
(R-I)
0.8
0.7
0.6
0.5
0.4

Fig. 3d

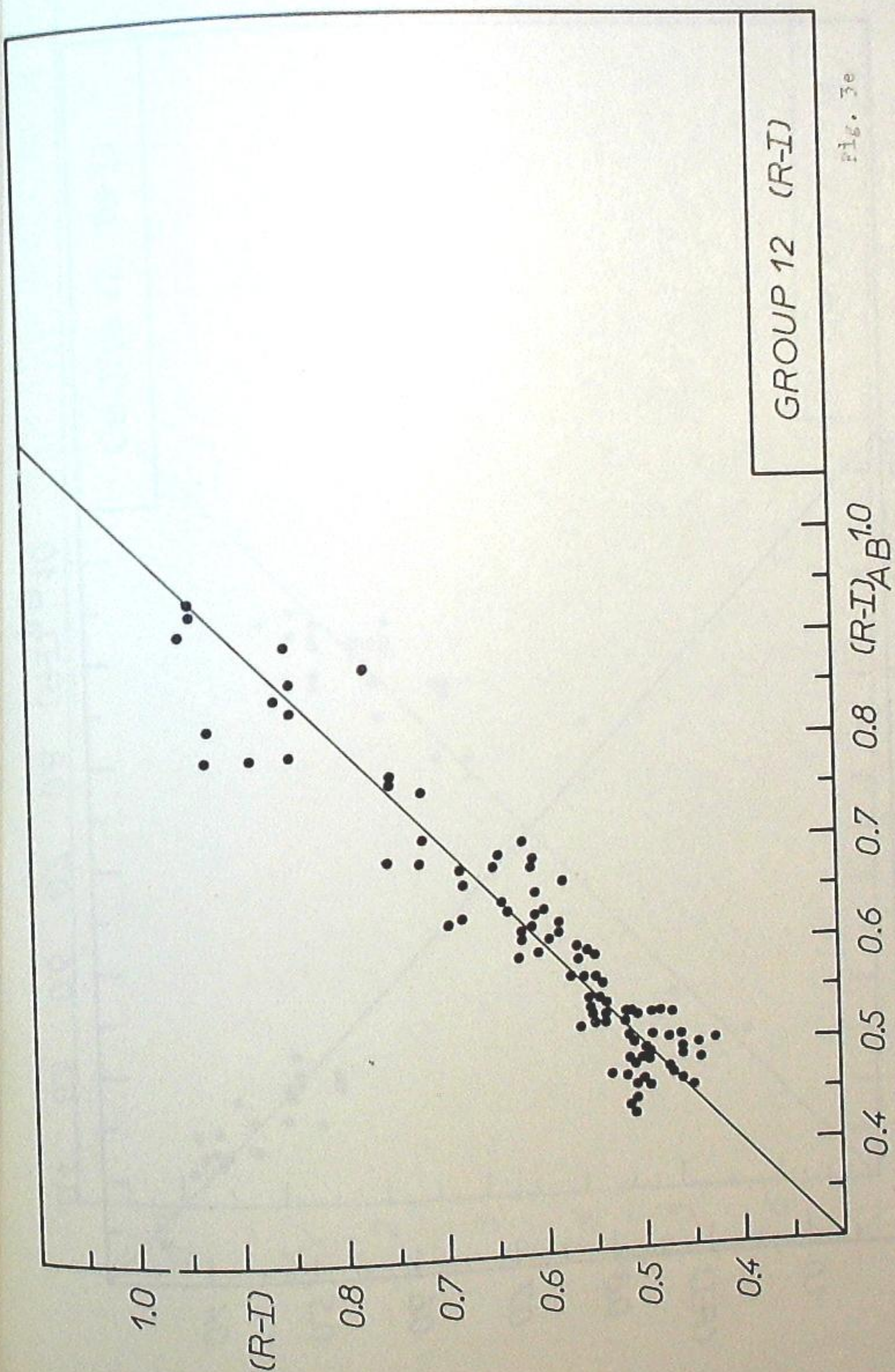
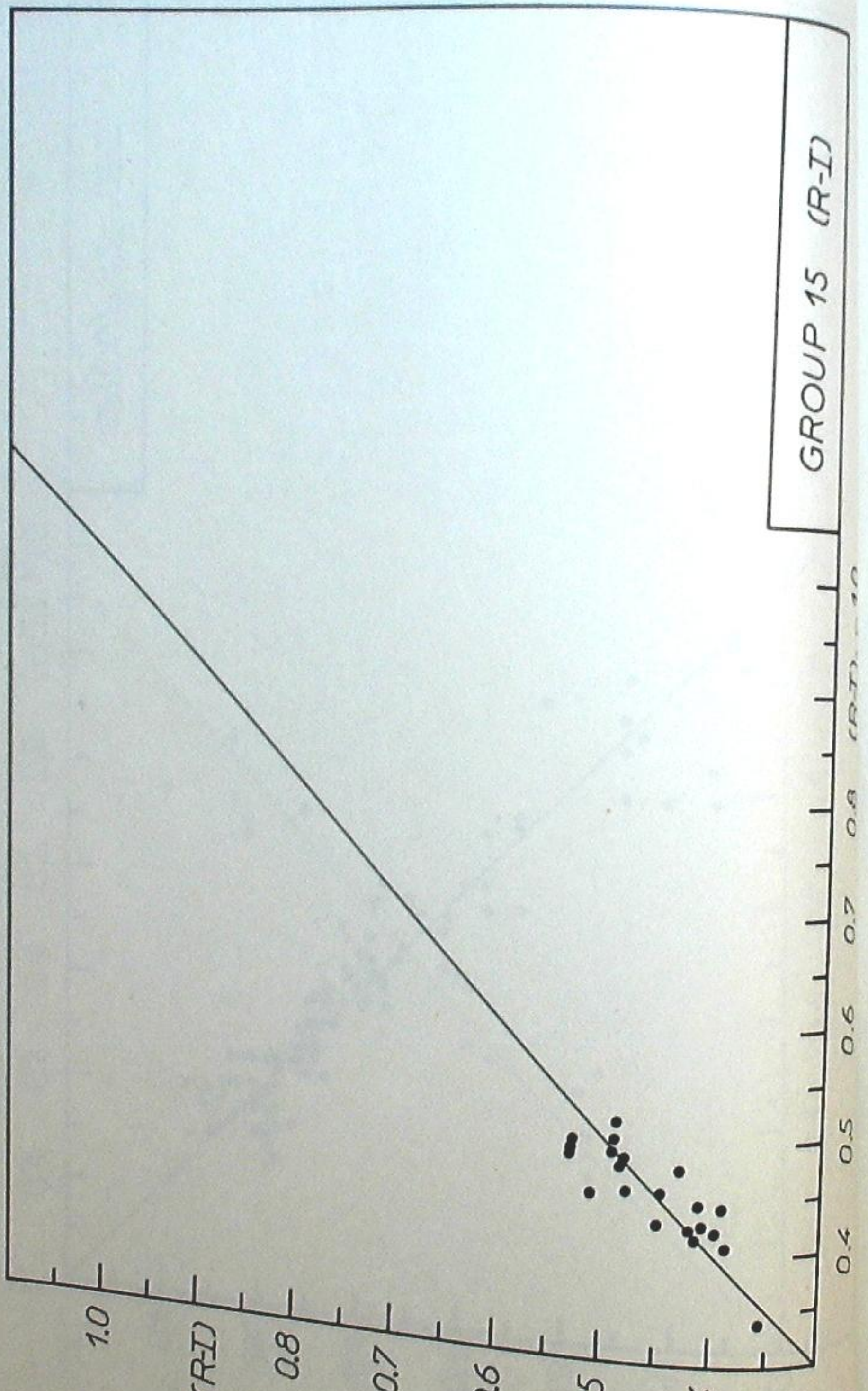
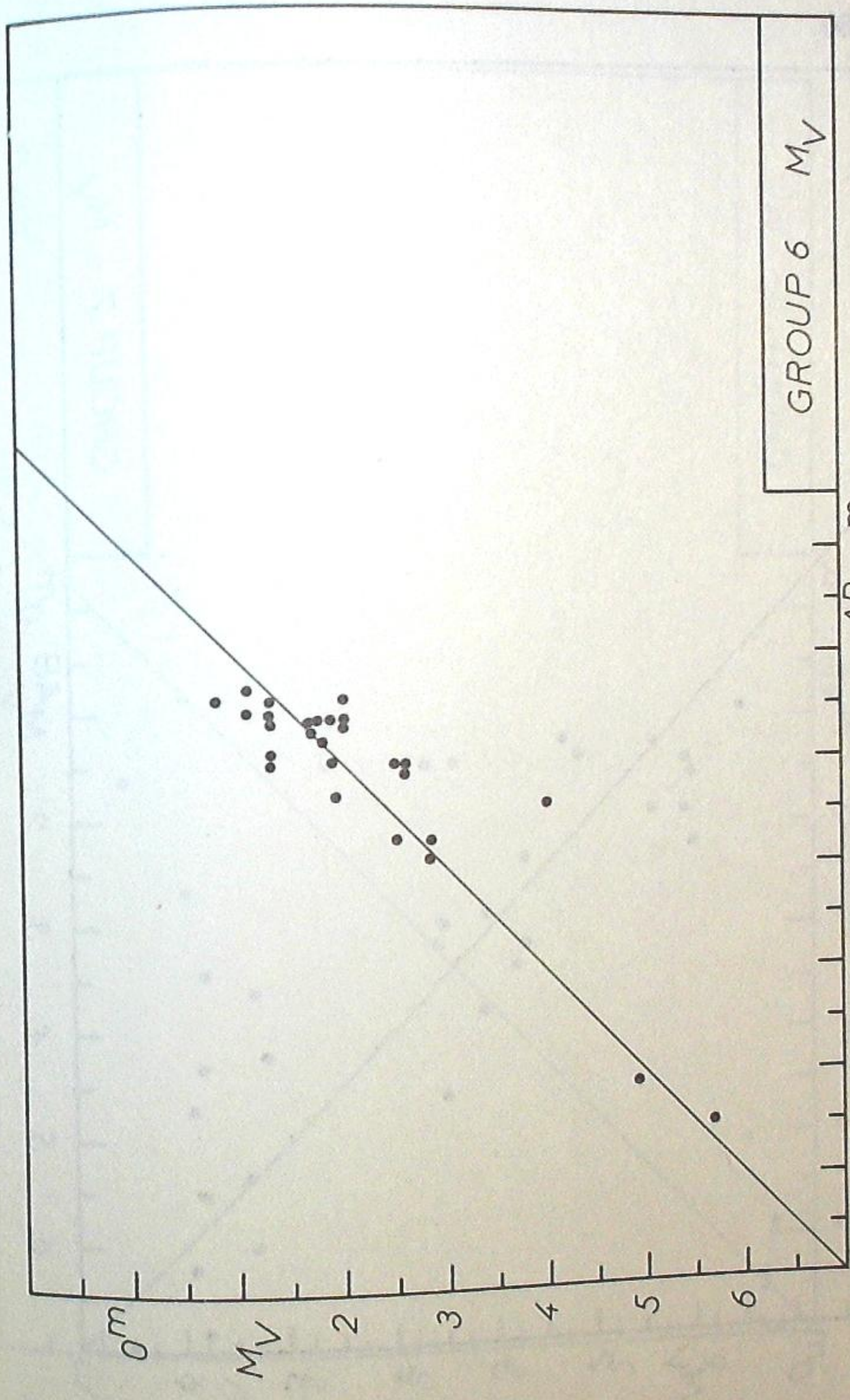

GROUP 12 (R-I)
0.4
0.5
0.6
0.7
0.8
$(R-I)_{AB}$
1.0
1.0
(R-I)
0.8
0.7
0.6
0.5
0.4

Fig. 3e


GROUP 15 (R-I)
(R-I)
0.4
0.5
0.6
0.7
0.8
1.0
(R-I)
0.4
0.5
0.6
0.7
0.8


GROUP 6 M_V
0^m
M_V^{AB}
2
3
4
5
6
0^m
M_V
2
3
4
5
6

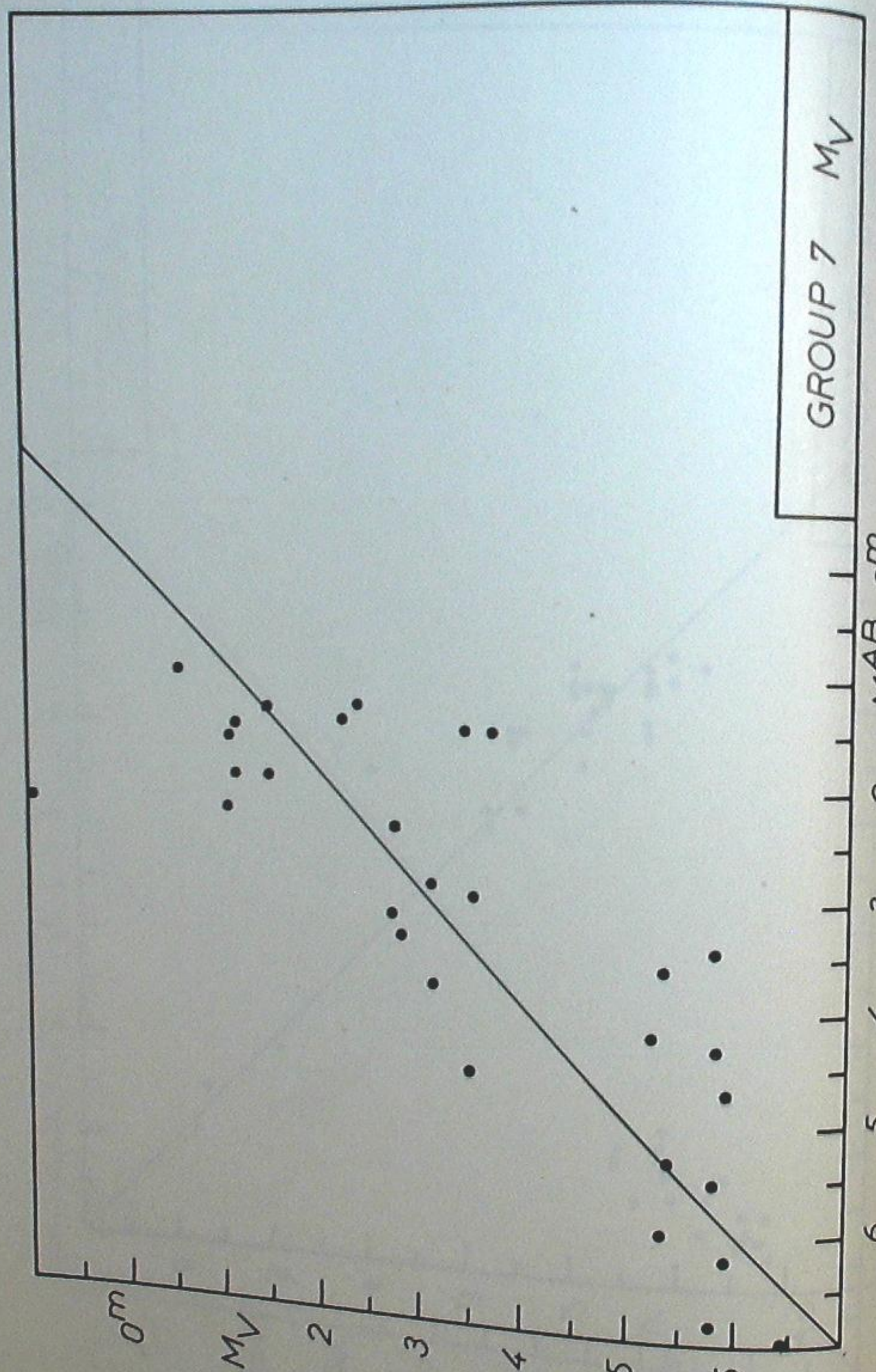


Fig. 4b

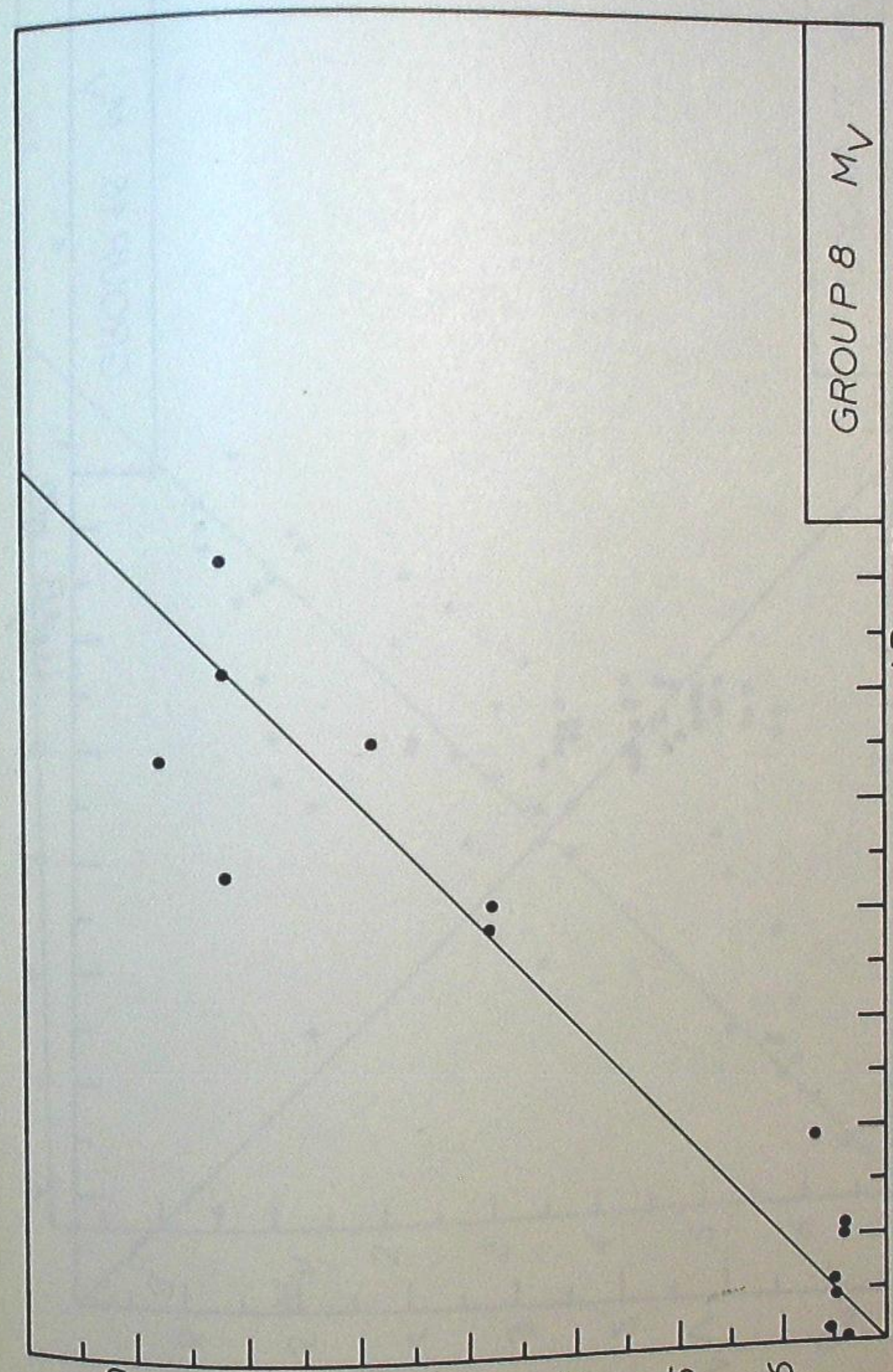
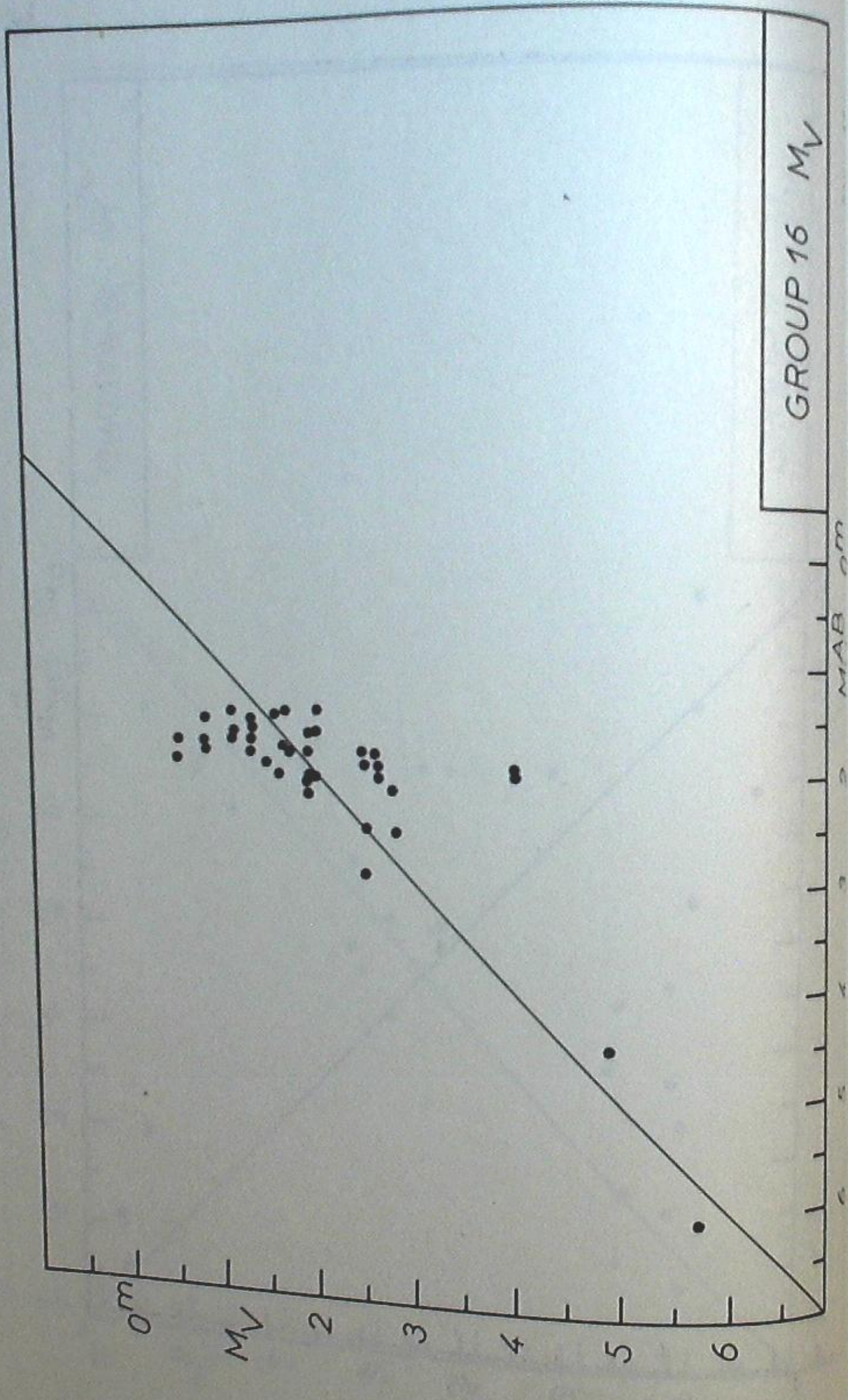
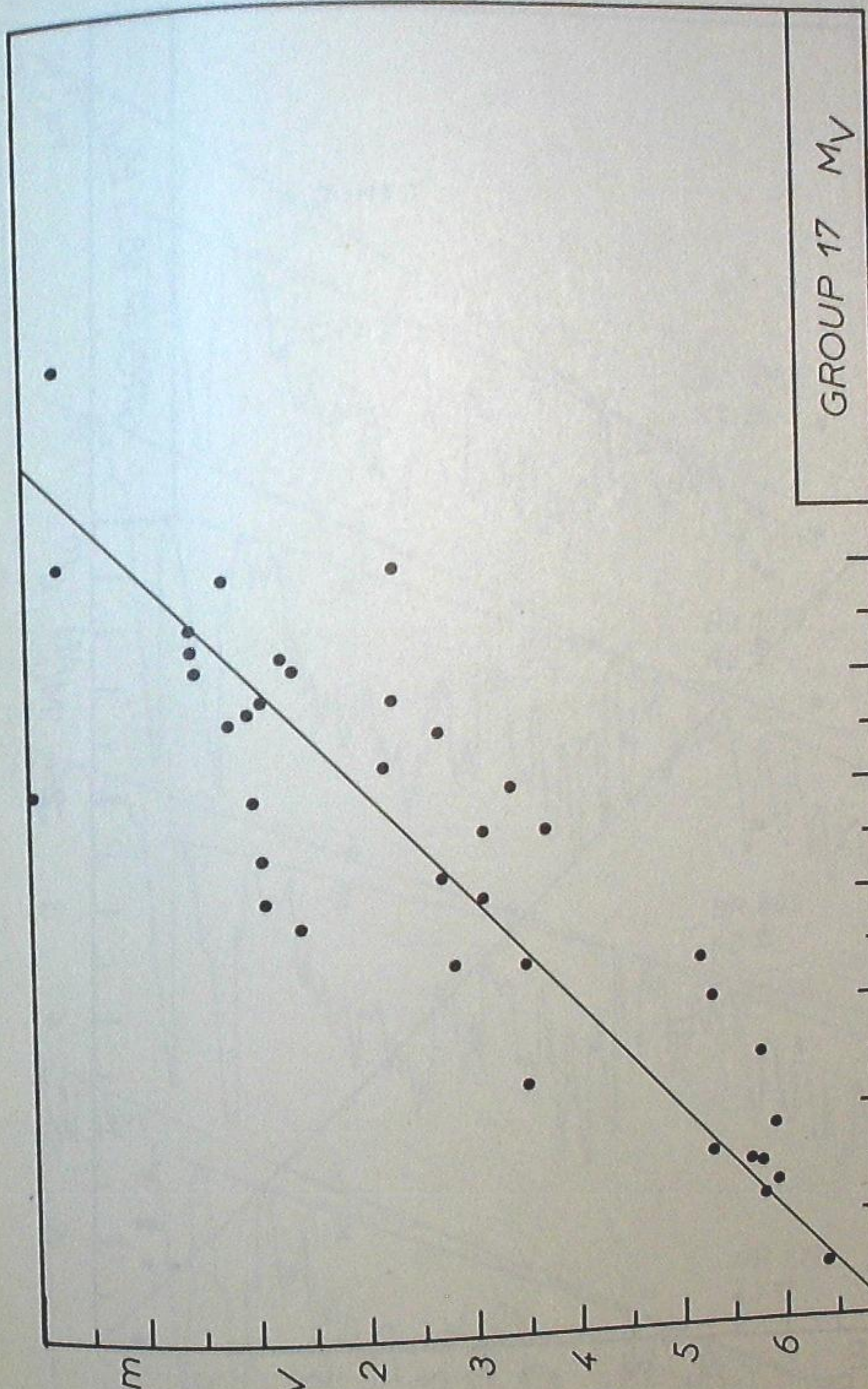


Fig. 4c



GROUP 16 M_V
0^m
M_V
2
3
4
5
6
M_V^{AB}



GROUP 17 M_V
0^m
M_V
2
3
4
5
6
M_V^{AB} 0^m
2
3
4
5
6

Fig. 4e

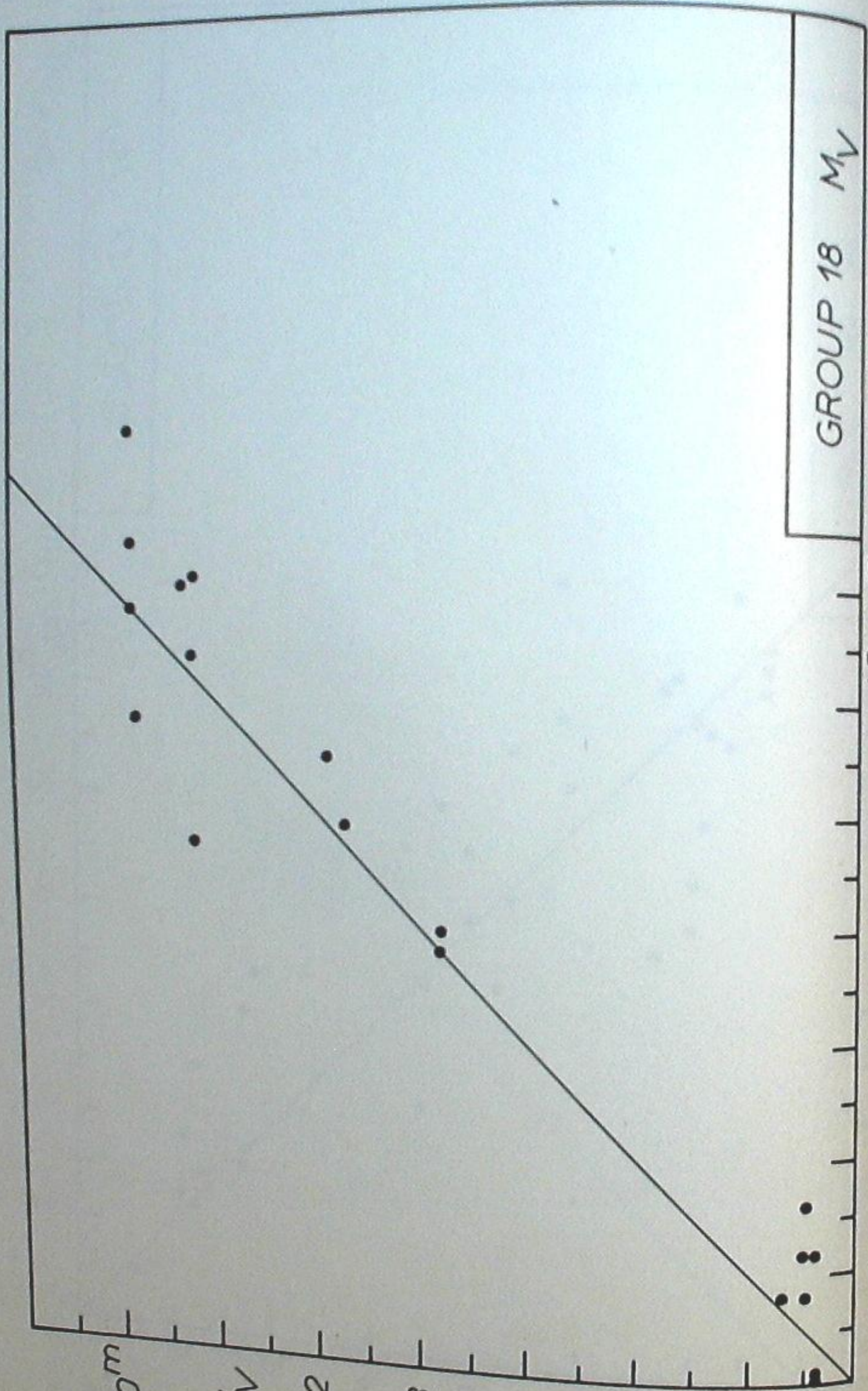

GROUP 18 M_V
M_V
M_{AB}^{V}
0^m
2
3
4
5
6

Fig. 4

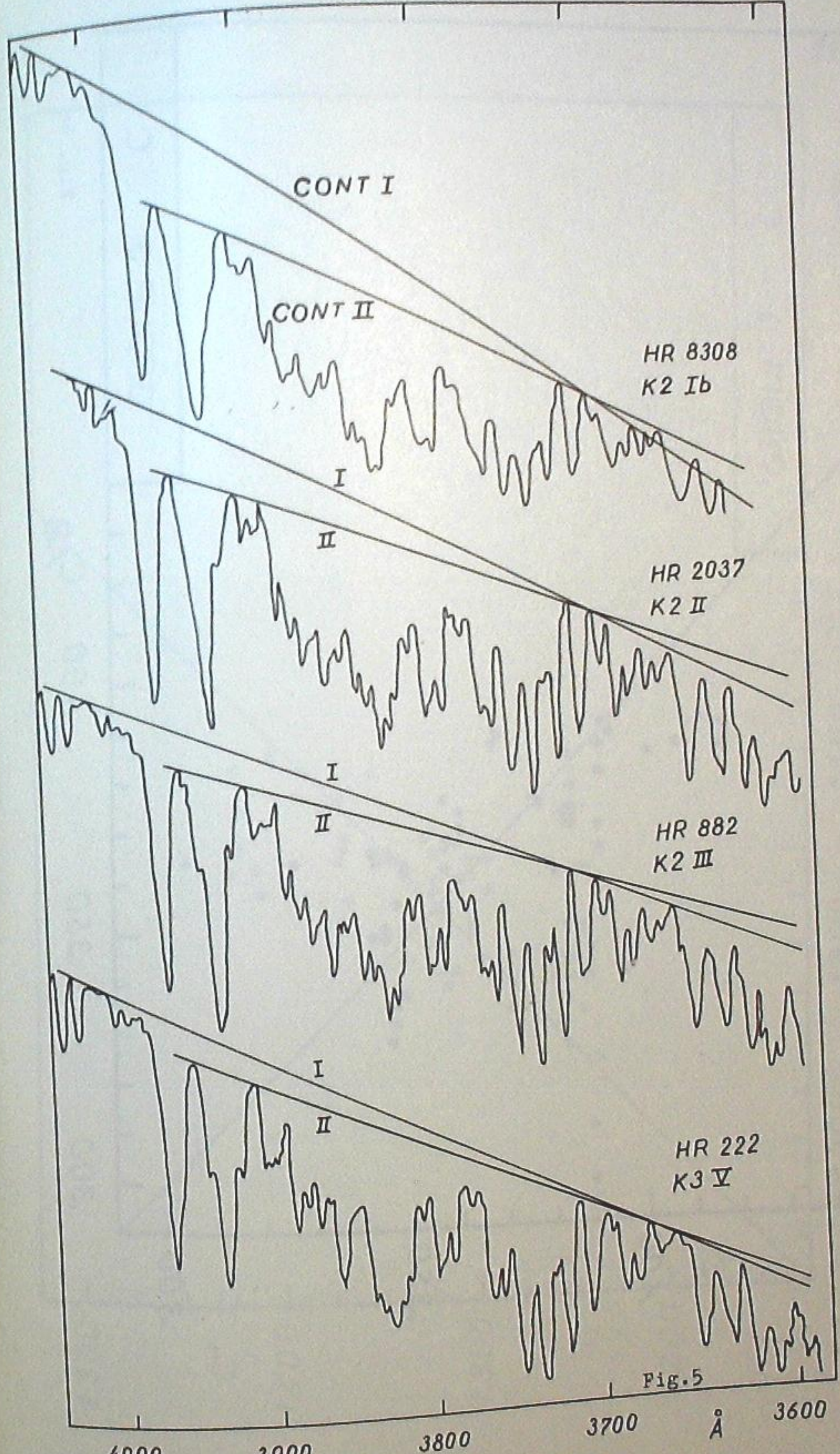

CONT I
CONT II
HR 8308
K2 Ib
I
II
HR 2037
K2 II
I
II
HR 882
K2 III
I
II
HR 222
K3 V
4000
3900
3800
3700
Å
3600

Fig.5

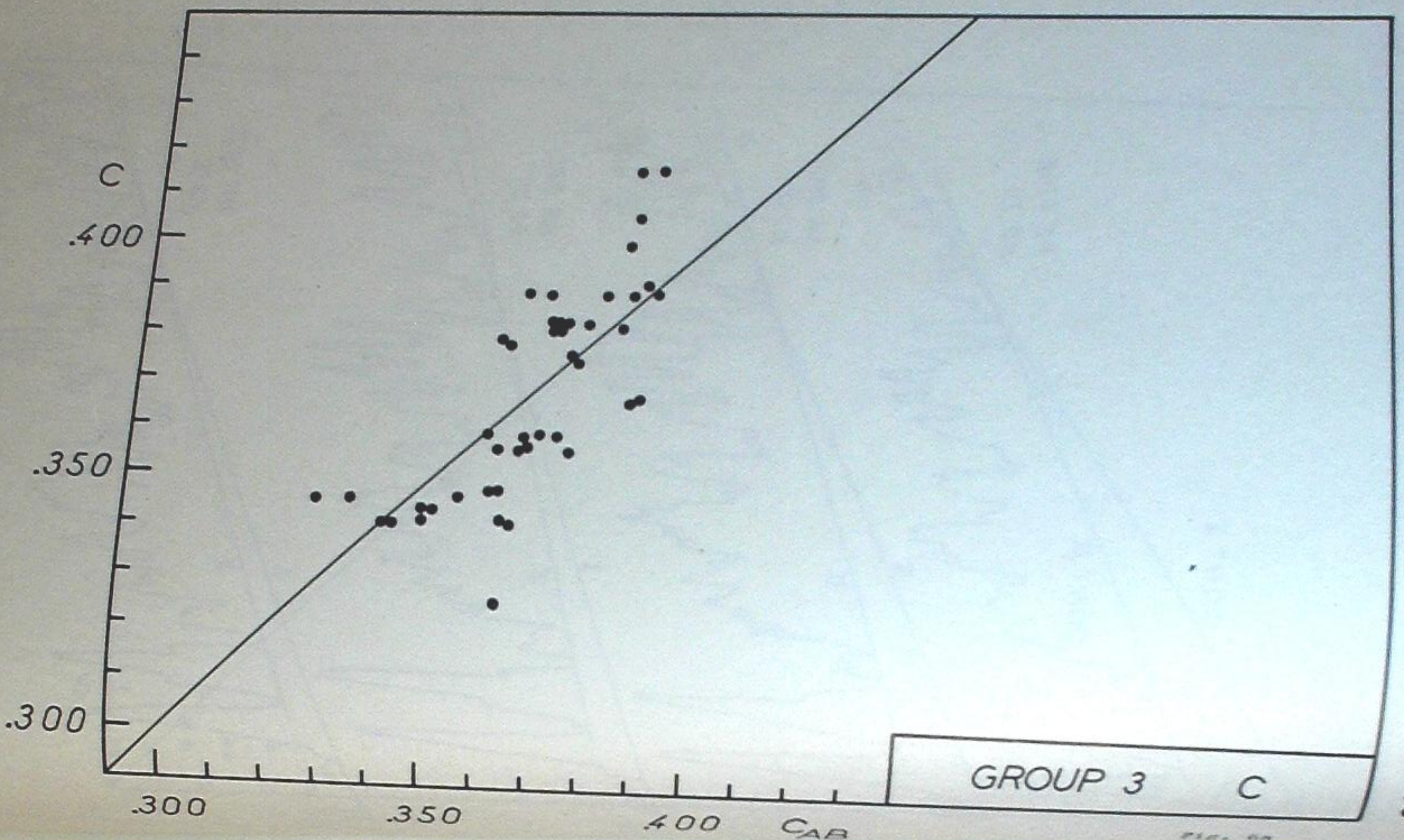

C
.400
.350
.300
.300
.350
.400
C_{AB}
GROUP 3 C

Fig. 6a

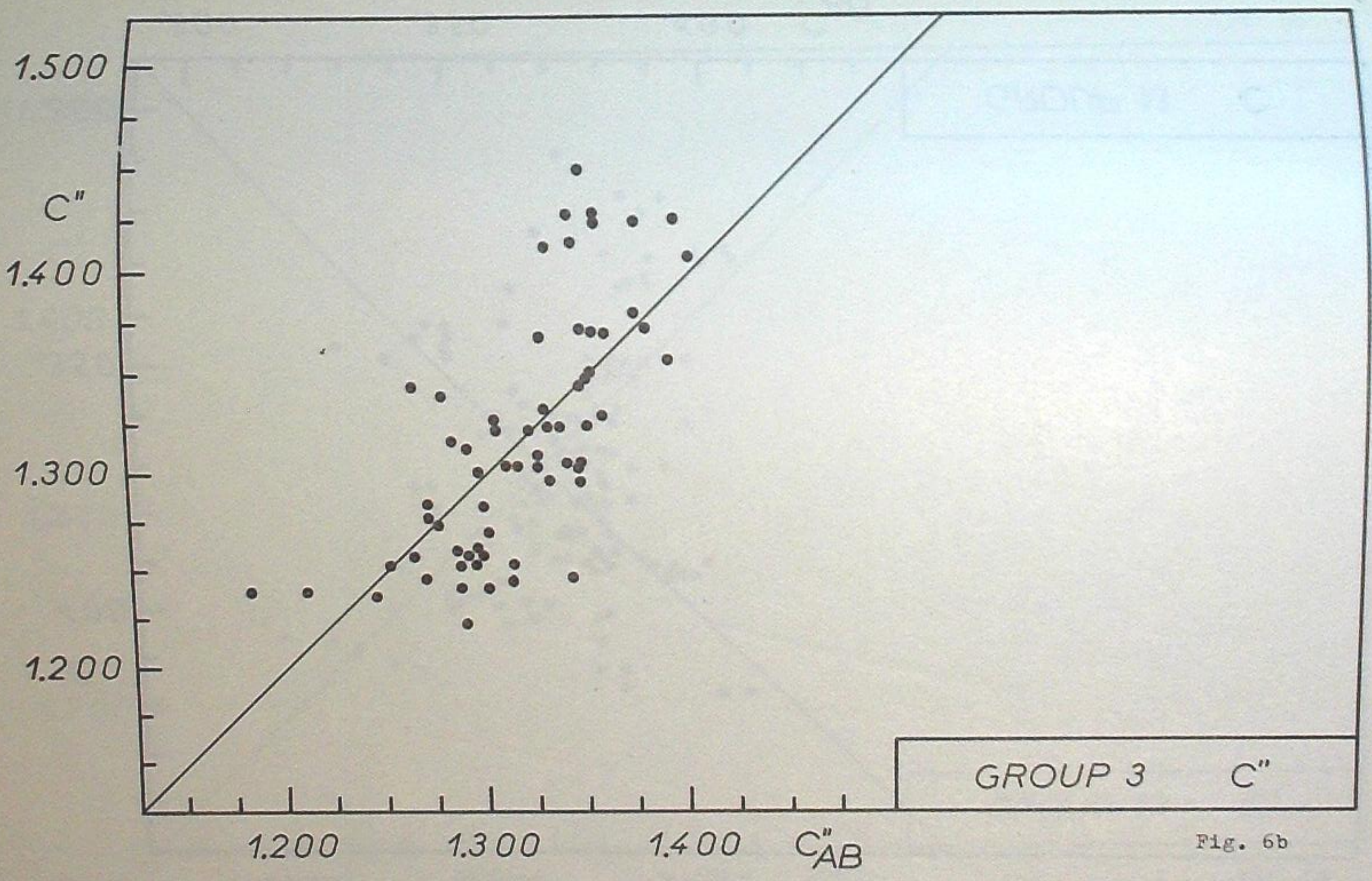
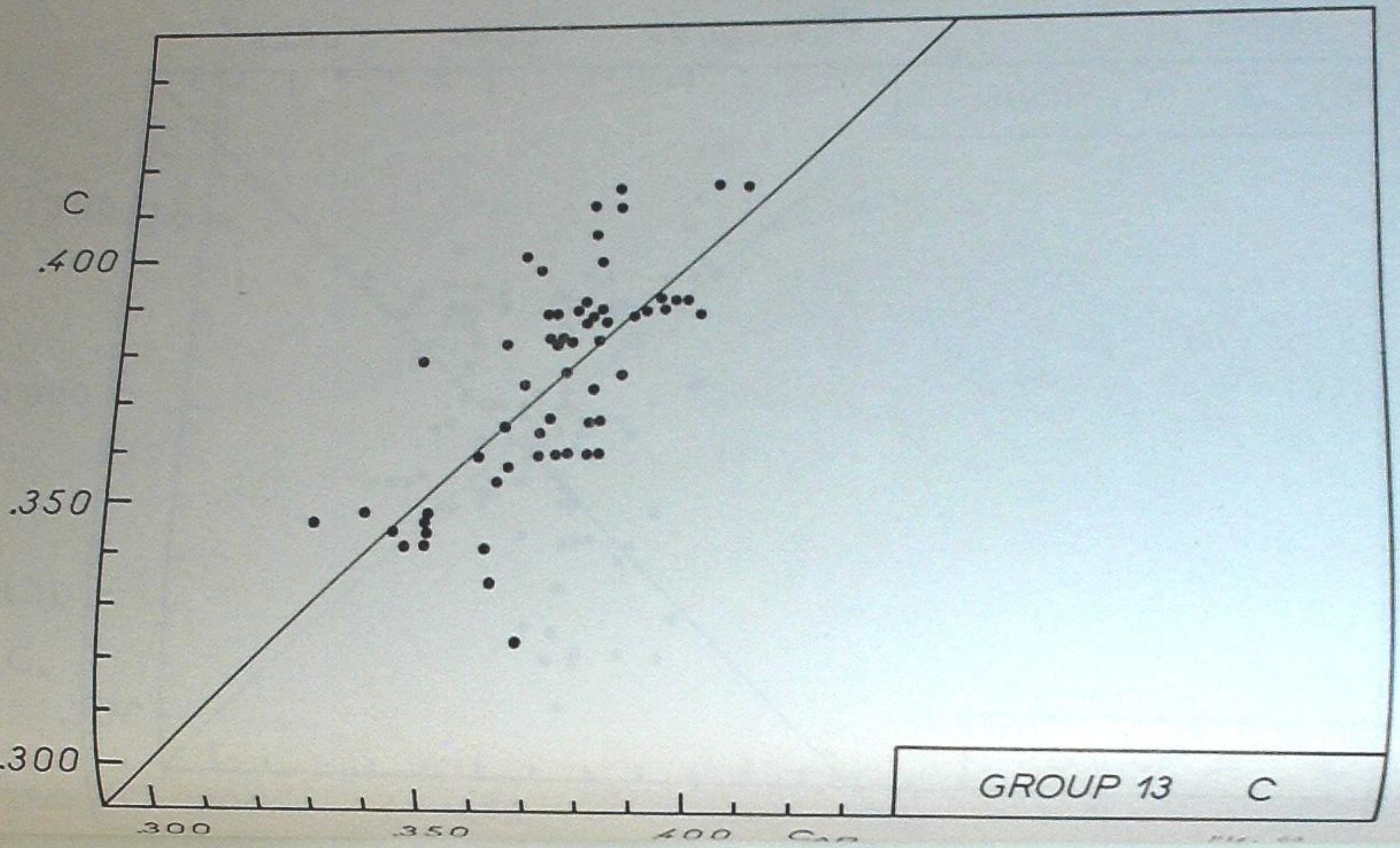

1.500
C"
1.400
1.300
1.200
1.200
1.300
1.400
C''_{AB}
GROUP 3 C"

Fig. 6b


C
.400
.350
.300
.300
.350
.400
GROUP 13 C

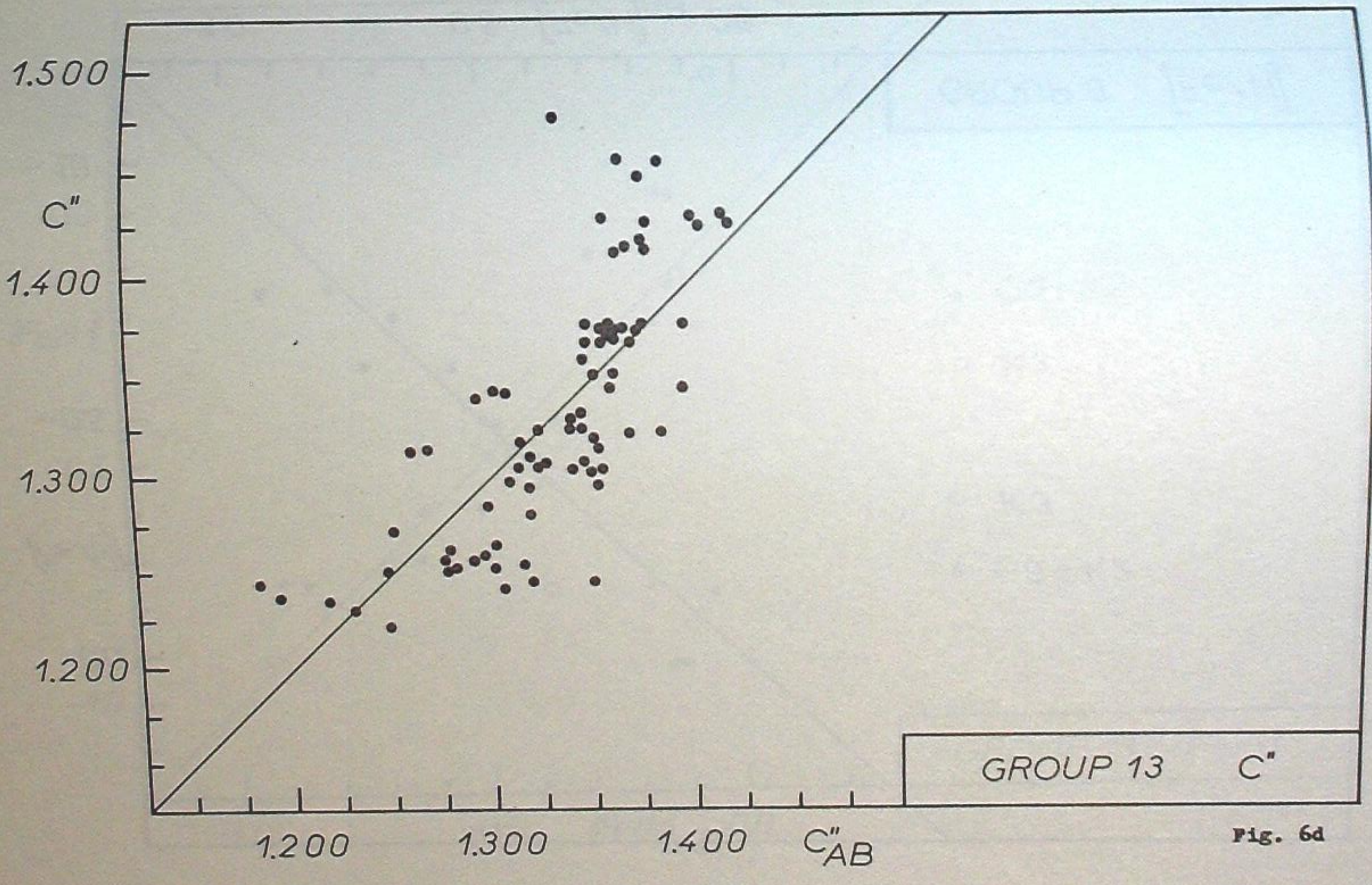

1.500
C"
1.400
1.300
1.200
1.200
1.300
1.400
C"AB
GROUP 13 C"

Fig. 6d

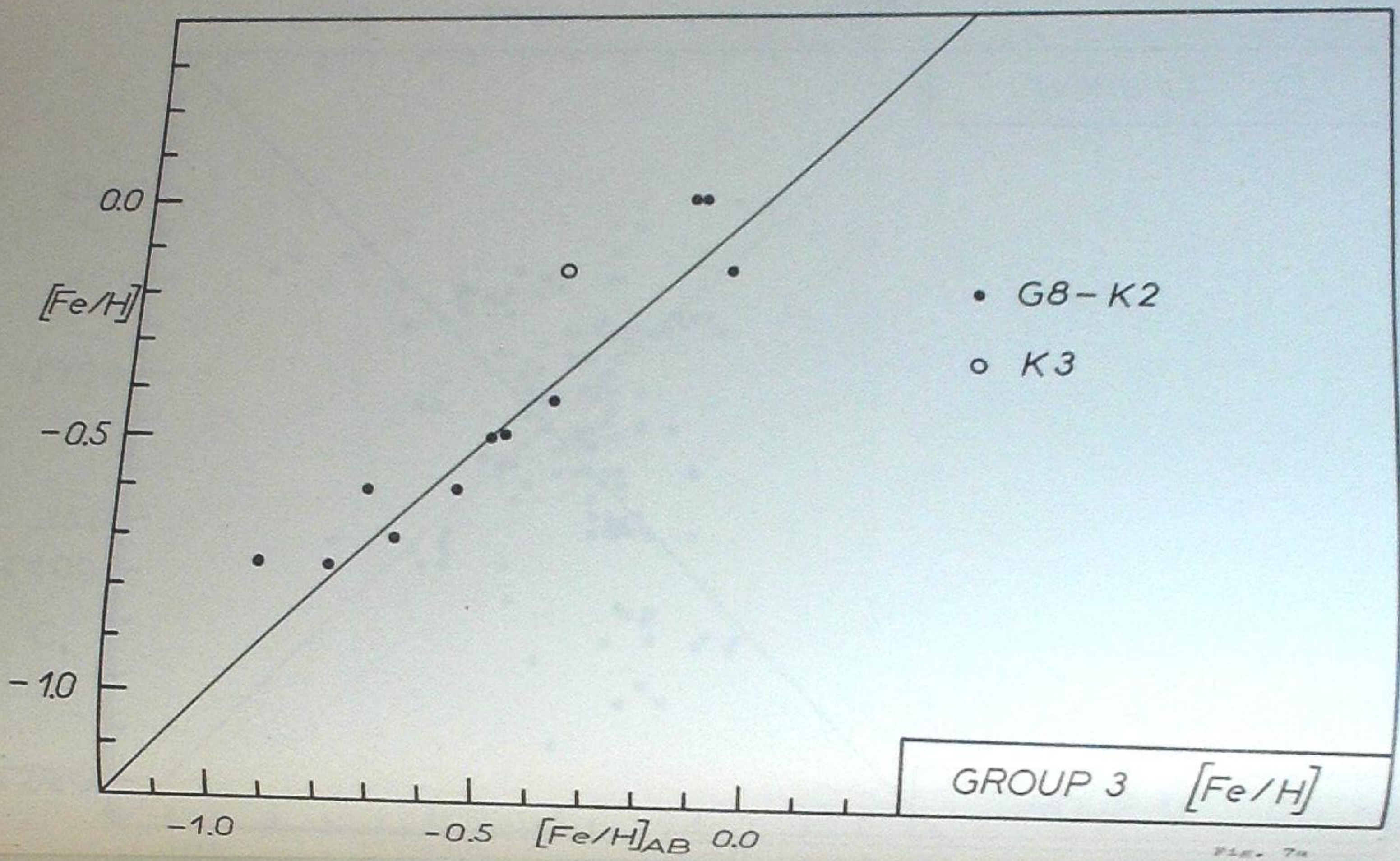

0.0
-0.5
- 1.0
[Fe/H]
-1.0
-0.5
[Fe/H]$_{AB}$
0.0
• G8 – K2
○ K3
GROUP 3 [Fe/H]

Fig. 7a

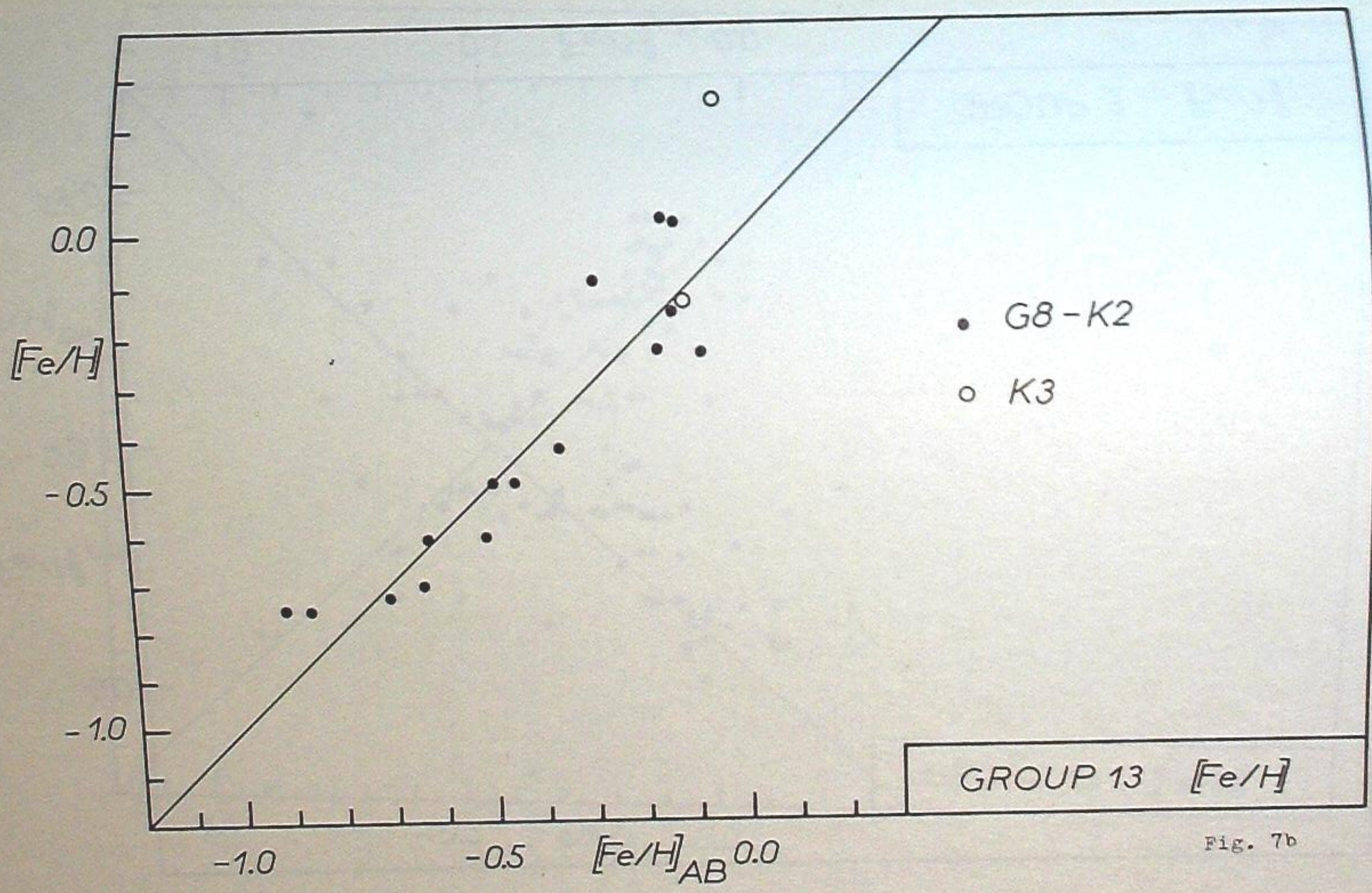

0.0
-0.5
- 1.0
[Fe/H]
-1.0
-0.5
[Fe/H]$_{AB}$
0.0
• G8 – K2
○ K3
GROUP 13 [Fe/H]

Fig. 7b

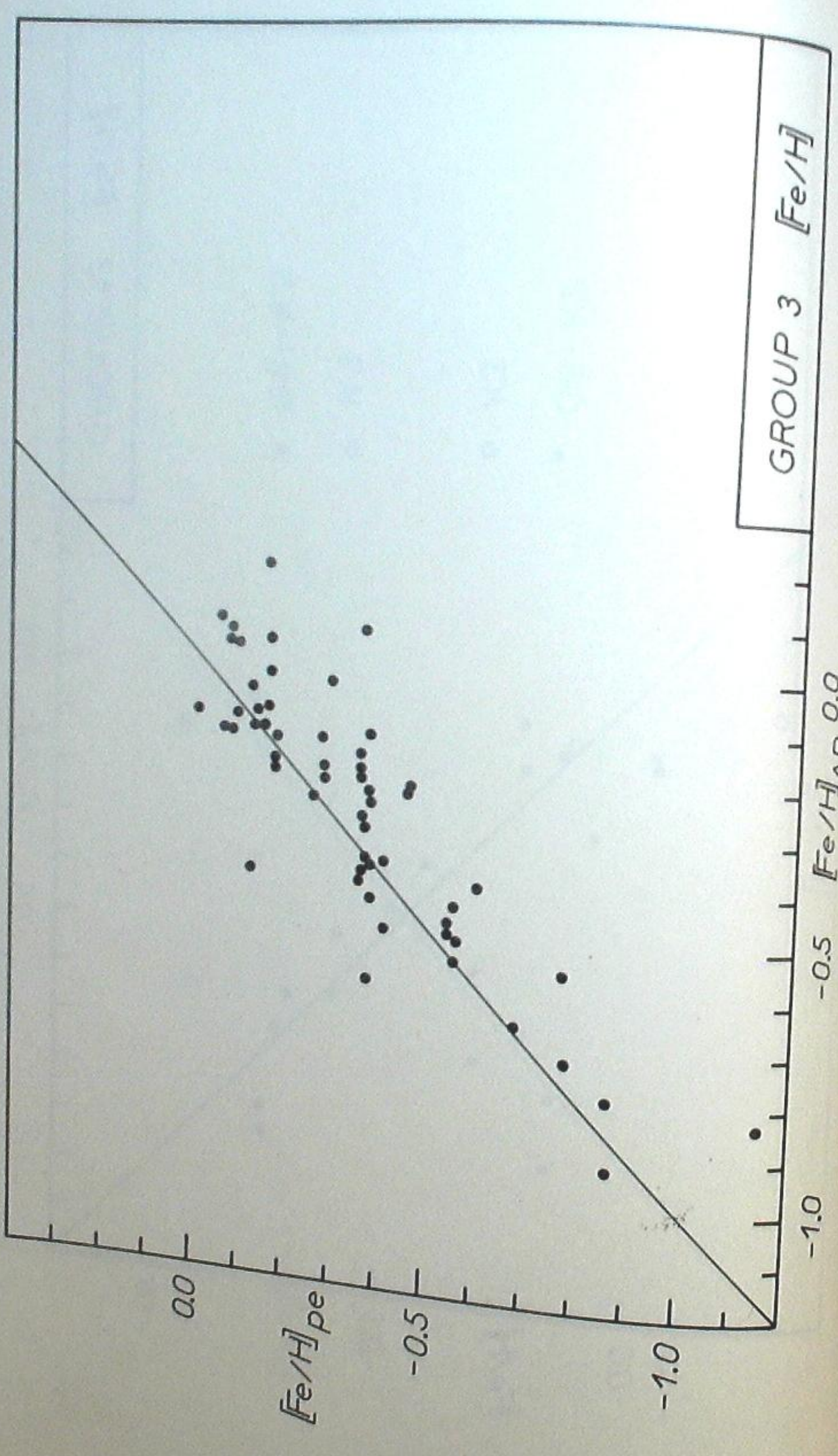

GROUP 3 [Fe/H]
[Fe/H]$_{AB}$
0.0
-0.5
-1.0
[Fe/H]$_{pe}$
0.0
-0.5
-1.0

Fig. 8a

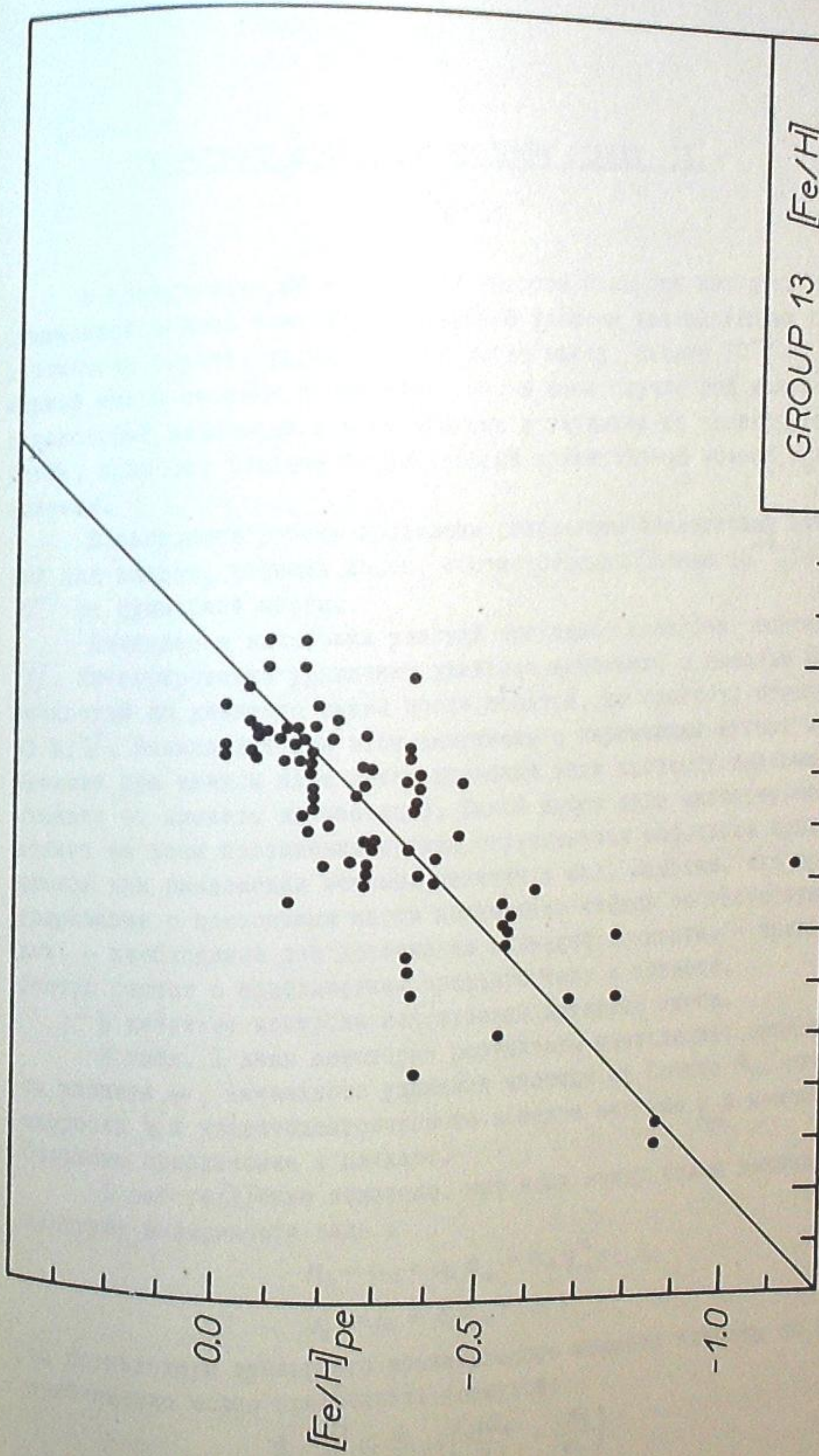

GROUP 13 [Fe/H]
[Fe/H]$_{AB}$
0.0
-0.5
-1.0
[Fe/H]$_{pe}$
0.0
-0.5
-1.0

Fig. 8b

აბასთუმნის ასტროფიზიკური ობსერვატორიის ბიულეტენი № 39, 1970
БЮЛЛЕТЕНЬ АБАСТУМАНСКОЙ АСТРОФИЗИЧЕСКОЙ ОБСЕРВАТОРИИ № 39, I970

К ВОПРОСУ О СУТОЧНОМ ВРАЩЕНИИ ПЛАНЕТ. II.

Р.И.КИЛАДЗЕ

В предыдущих работах[I],[2] автором построен класс орбит в ограниченной задаче трех тел, названный классом квазикруговых орбит; рассмотрен случай, когда планета имеет массу, равную 10^{-3} от суммарной массы системы и показано, что в этом случае рой малых частиц, в некоторый начальный момент времени движущихся по квазикруговым орбитам, приносит планете отрицательный вращательный момент при столкновении.

В настоящей работе приведены результаты аналогичных вычислений для планет, имеющих массы, соответственно равные 10^{-4}, 10^{-5} и 10^{-6} от суммарной массы.

Вычисление начальных условий проведено способом, описанным в [I]. Интегрирование уравнений движения выполнено с помощью ЭВМ с точностью до девятого знака после запятой, по способу, предложенному в[3]. Вычисления при этом выполнены с переменным шагом: интервал времени при каждом шаге интегрирования взят пропорциональным S_0(расстояние от планеты до частицы). Такой выбор шага интегрирования позволяет на всем протяжении орбиты ограничиться небольшим количеством членов при разложении искомых величин в ряд. Заметим, что при интегрировании с постоянным шагом количество членов соответствующих рядов, - необходимое для достижения заданной точности, - чрезвычайно быстро растет с приближением третьего тела к планете.

В качестве контроля использован интеграл Якоби.

В табл. I даны некоторые результаты вычислений: значения массы планеты μ, начального удаления частицы от Солнца R_0, начальной скорости V_0 и планетоцентрического момента частицы q_m в момент её наибольшего приближения к планете.

В работе[2]было показано, что если между этими величинами существуют зависимости вида :

$$R_0 = a_0 + a_1 q_m + a_2 q_m^2 + \dots, \qquad (I)$$

$$V_0 = b_0 + b_1 q_m + \dots,$$

то производную суммарного вращательного момента планеты по массе приближенно можно представить формулой:

$$\frac{1}{r_0}\cdot\frac{dQ}{d\mu} \approx \frac{2}{3}\mu\left(\frac{2a_2}{a_1} + \frac{b_1}{b_0}\right), \qquad (2)$$