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ANALYSIS OF SOLAR IMAGES WITH THE SADAF FLYING-SPOT

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Introduction

In the last years many problems in optical solar physics (flares and sunspot high resolution observations, brightness oscillations, macroscopic and small scale velocity fields, chromospheric fine structures, magnetic knots, etc.), together with the recent space observations (e.g., all the Skylab experiments), asked for an automatic photometric analysis of a huge amount of observational material. For these purposes, and for the study of more general applications of high speed computer controlled devices in the photometric analysis of extended sources in astrophysics, we used the S.A.D.A.F. computer controlled flying-spot machine of the Istituto di Elaborazione dell'Informazione - CNR (Pisa), extensively described elsewhere (Azzarelli and Panicucci, 1972; Carlesi and Montanari, 1973; Carlesi, 1975; Azzarelli et al., this conference).

Here we like to report the results of two different works of solar physics for which we used the S.A.D.A.F. machine.

Analysis of Hα active regions

With a photographic isodensitometric method it was possible to obtain some new and interesting results about the photometric evolution of solar flares and, more generally, of Hα active regions (Falciani et al., 1972; Falciani and Rigutti, 1972 a, b). In the present work we studied some series of Hα solar filtergrams (≈ 5000), obtained during 1969 (May 15 - 16 - 17 - 25 and Oct. 25 - 27) at the Athens National Observatory. The measurement method, the performances and several tests of the equipment are described by Azzarelli et al. (1975). Essentially it is possible to monitor on-line on a CRT memory display all the scanned regions and through a joystick it is easy to select some particularly interesting areas for further detailed reductions. In Fig. 1 a reproduction of an analysed Hα filtergram is given, while in Fig. 2 it is shown the same active regions present in Fig. 1, projected on the CRT memory display together with the limits, controlled through the joystick, of the areas to be extracted from the general digitization matrix for further elaborations (minors). The little square below indicates the area over which we obtained the mean photographic density of the undisturbed surrounding chromosphere.

All the working procedures of the equipment (scanning parameters determinations, output peripherals, magnetic tape memorization options, jump of not interesting photograms, number of the minors to be extracted, etc.) are controlled through a flexible and interactive program. At the end only the photometric digitized data of the selected minors and of the corresponding mean undisturbed chromosphere are loaded on magnetic tape. We point out the importance of this interaction between the operator and the flying-spot machine in order to be sure to extract only the information needed for the programmed research (in our case the bright Hα active regions); this allows an efficient data compression. Moreover, this interaction is particularly useful in the case that the observational material has not been obtained with a completely automatic, computer controlled telescope. In fact, drift of the guiding system of the telescope, absence of reference position marks in the field, strong variations in the sky conditions may cause serious troubles to the interpretation of the final data if we could not be able to monitor the actual scanned area and its photometric conditions.

Tha raw data are converted (with an off-line computer code) into intensity values, measured in unit of the mean undisturbed chromosphere surrounding the event. Then we get, by interpolation, the projected area of the phenomenon A_j at a given intensity level j, the energy E_j emitted from a selected intensity level up to the maximum intensity present in the scanned area, the location of the brightest points and the isophotes maps of all the minor or of a given part of it (obtained through computer codes developed by Casalini and Cerri, 1975 a, b). The analysis of a time series of filtergrams provides the temporal evolutive curves of $A_j(t)$ and $E_j(t)$. Fig. 3 shows an example of evolutive curve $E_j(t)$.

From the examination of the behaviour of the obtained evolutive curves we can deduce that before the flash phase of the flare, usually defined roughly as the phase in which the brightest part of the flare grows up and expands, a contraction of the whole active area takes place, very probably preceded by a sort of instability, viz. some intensity fluctuations of the surrounding plage. This fact needs to be checked in the future, with the maximum care, on a large set of events, observed also with sufficient time resolution during all the pre-flare phase. This requires ad-hoc observational material, because up-to-now we are not able to establish time and position for the birth of a flare and, very often, the beginning of a set of observations with good time resolution coincides with the beginning of the flare itself.

After the flash phase an approximately exponential decay of the emitted energy vs. time is observed, with higher time constants for higher j values.

The isophotes maps show that the evolution of the brightest points in the flare (kernels) is characterized by a rapid increase in the emission of a very small area, followed subsequently by a sort of diffusion of the emission from the kernels to the outer parts of the plage. In Figg. 4 ÷ 9 some examples of the isophotes development, obtained at some particularly interesting moments of the energy evolutive curves represented in Fig. 3, are given.

These results are in agreement with those obtained through direct scanning of the solar image by Argo et al. (1973). We like to stress that the latter authors selected from the solar image only the data concerning A_j, E_j and kernels location and all the other possible data and information were lost after the acquisition of the above quantities. With our method of analysis, on the contrary, we are able to extract the information we need, keeping unaltered all the information content of the photographic monocromatic image of the sun.

Similar data were obtained for bright plages too, but it seems not the case to discuss here these results and to enter in these details, even if very rapidly.

Possible oscillations of the chromospheric network

The complexity of the velocity field distribution in the solar photosphe re, as well as the wave motions in the photosphere itself (e.g., five minutes o- scillations in brightness, local velocity fields, temperature and so on) are well known. There are many valuable measurements and their theoretical interpretation is a matter of investigation, but with severe limits imposed by well established measured parameters.

On the contrary, for the chromosphere, the observational situation is far to be satisfactory. In fact the morphological appearance of the quiet chromosphere is much more complicated, showing a great number of fine structures and very small features (of the order of one arcsec or less), not uniformly distributed and orga- nized in some regular structures, recognizable but not objectively definable (su- pergranular cells, rosettes, bright and dark mottles, etc.). Hence, it is very hard to select a precise and well established point in a series of H_{α} images of the quiet solar chromosphere, because we must avoid the small displacements and form variations of the image due to terrestrial seeing effects (of the same order or greater of the fine structures themselves) and take into account the proper evo lution of the structures too.

Quantitative determinations of the intensity fluctuations of individual fine structures on high spatial resolution H_{α} filtergrams are, to our knowledge, those by Bhatnagar and Tanaka (1971) and Moore and Tang (1975), the latter refer ring nevertheless to sunspot umbral oscillations. Since it should be of great in terest for a complete understanding of the whole phenomenon to determine if these brightness oscillations occur in the chromosphere too and, possibly, to measure their period, we decided to analyse with the S.A.D.A.F. an excellent series of 1800 high spatial resolution H_{α} -0.6Å filtergrams of the quiet chromosphere, taken with a constant time resolution of 10 sec.

Some hardware modifications enable us to display very satisfactorily on the CRT memory monitor small features with low contrast (of the order of some per cent). Fig. 10 shows a CRT image of a portion of a chromosphere filtergram and all the details in the original are clearly visible in the CRT reproduction.

In this work we are interested in a pre-analysis of the filtergrams, performed by the system itself during the scanning procedures, so that it can be possible to acquire only few and significant data needed for the determination of the possible oscillations and not all the digitization matrices. It has been deve loped a software program able to perform the recognition of the projected clock image and to establish a coordinate system on the edges of the external square of the clock image itself. Since the telescope, used to take these filtergrams, was photoelectrically guided with an accuracy of the order of 1 arcsec, we are sure, with this procedure, to fix the above mentioned coordinate system of the solar i- mage with the same accuracy. We pick out, at the beginning of the scanning, some points in the chromospheric network (i.e., supergranulation cells center and bor- ders, knots between two or more supergranules, etc.) and we select very small areas centred on these points (represented by the small white rectangles in Fig. 10), in order to extract the intensity data not only from a single chromospheric feature.

The program performs also some tests to be sure of the right position of the selected areas (visually controlled also on the CRT reproduction) before the acquisition of the measurements for the following off-line study. These measurements are then analyzed with the HP Fourier Analyzer System of the I.E.I. in order to establish if some systematic fluctuations are present and their period. Up-to-now only test scannings were made, showing the right working conditions of all the above described procedures; the final scanning of all the 1800 filtergrams will be operated in the next few days.

We stress here that this analysis represents a typical example of the use of the random access possibility of the S.A.D.A.F. system; without this fundamental feature of the S.A.D.A.F. it should have been impossible to carry out a work as that described above.

We like to conclude by pointing out that these works are the first attempts in solar physics to develop hard and softwares facilities to make image quantitative photometry of a large amount of observational material. Forgetting many initial troubles (very often related to the quality of the analysed material, not completely suitable for automatic analysis), we stress the satisfactory results till now obtained and the promising and new possibilities of this type of impersonal diagnostics in solar physics. Finally, it shall be possible to use all these experiences (hardware developments, algorithms and softwares) for the study of the photometric structure and evolution of all types of extended sources images, especially in astrophysics.

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Captions for Figures

Fig. 1 - Reproduction of an analysed Hα filtergram.

Fig. 2 - Active regions (present in Fig. 1) projected on the CRT memory display, with digitization minors limits.

Fig. 3 - Energy evolutive curves of May 26, 1969 solar flare.

Fig. 4 - Isophotes map corresponding to the point A in Fig. 3.

Fig. 5 - Isophotes map corresponding to the point B in Fig. 3.

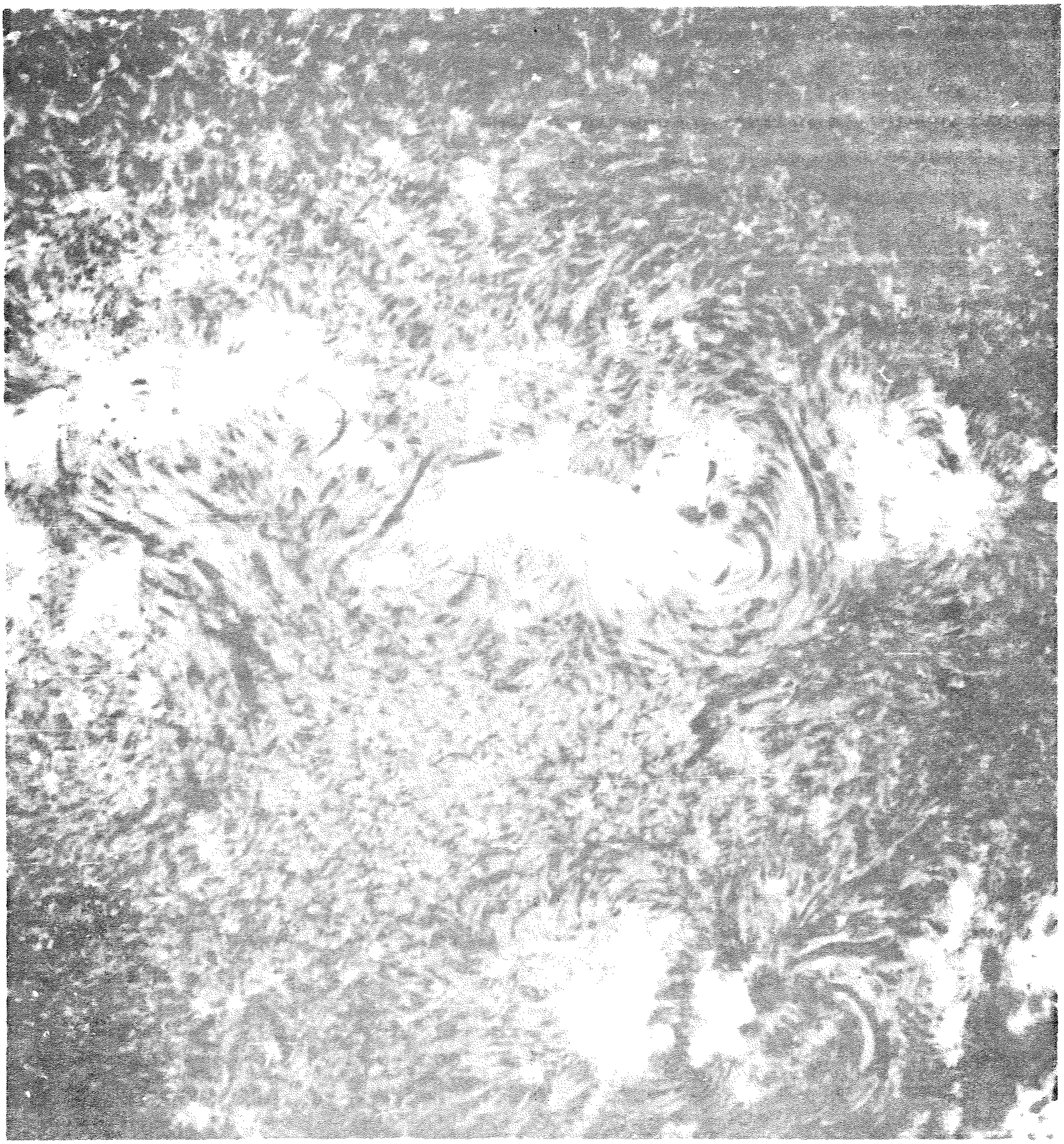
Fig. 6 - Isophotes map corresponding to the point C in Fig. 3.

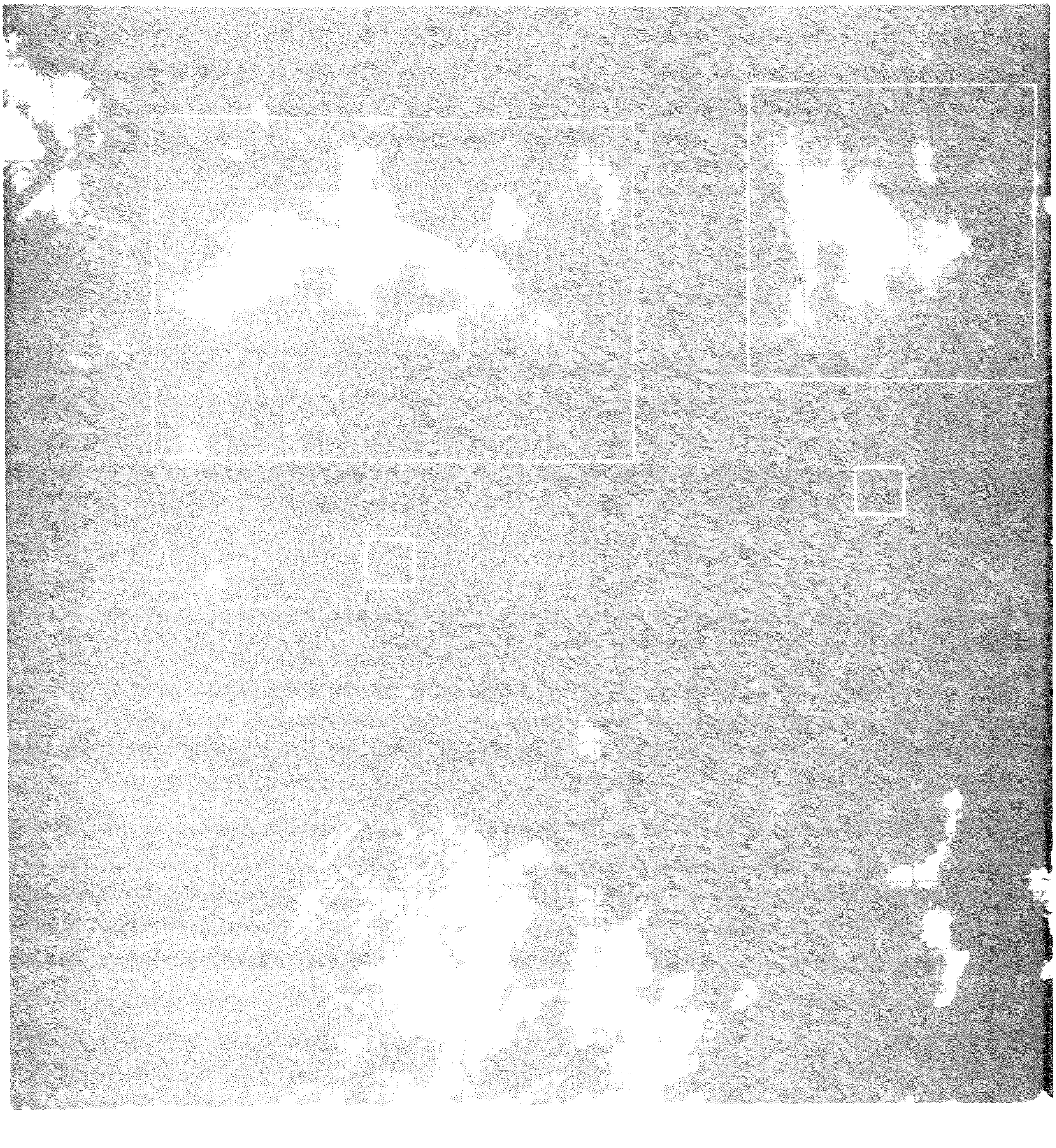
Fig. 7 - Isophotes map corresponding to the point D in Fig. 3.

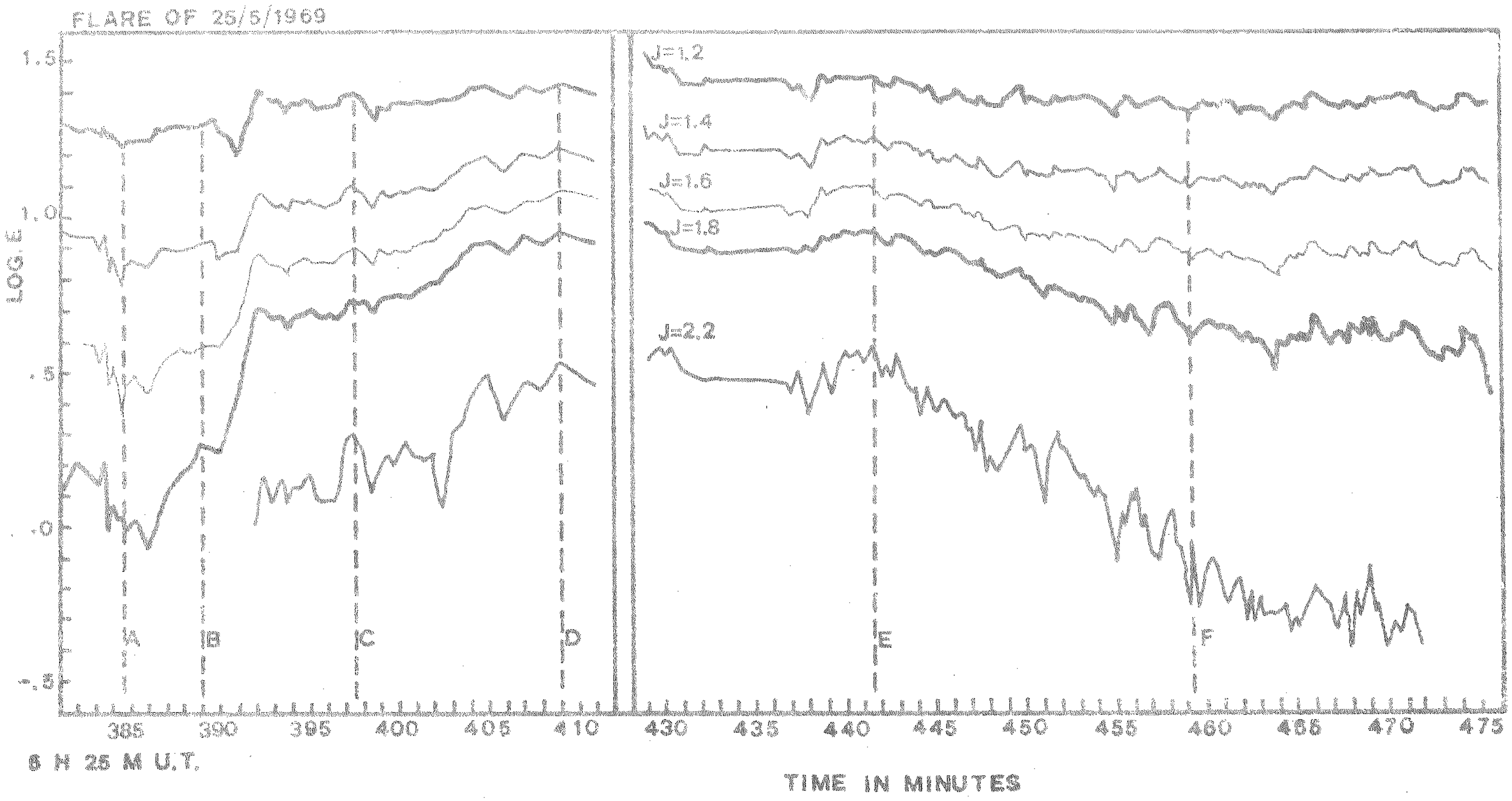
Fig. 8 - Isophotes map corresponding to the point E in Fig. 3.

Fig. 9 - Isophotes map corresponding to the point F in Fig. 3.

Fig.10 - Solar quiet chromosphere Hα -0.6Å image projected on the CRT memory display.






FLARE OF 25/5/1969
LOG.E
1.5
1.0
.5
.0
-.5
J=1.2
J=1.4
J=1.6
J=1.8
J=2.2
A
B
C
D
E
F
385
390
395
400
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410
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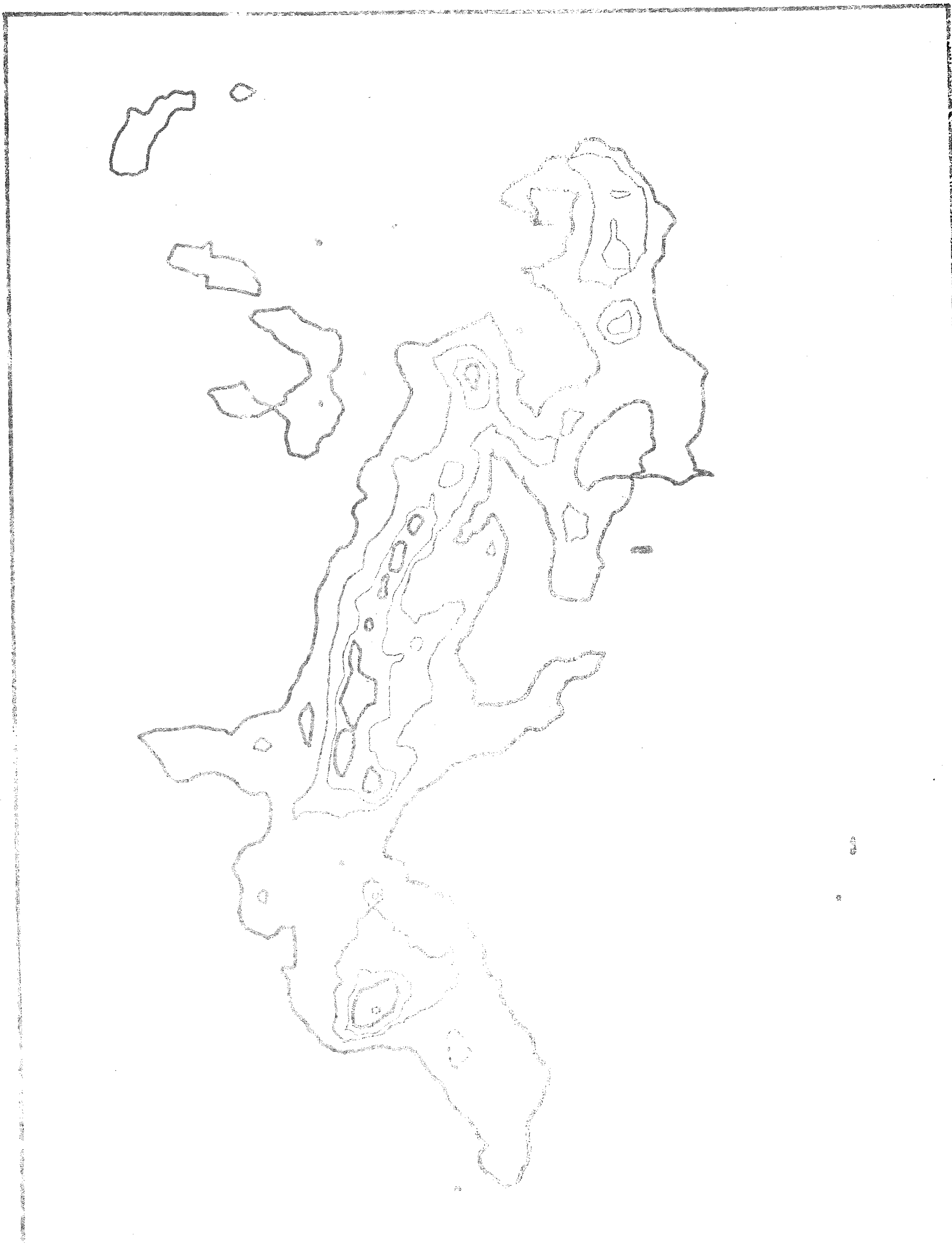
475
6 H 25 M U.T.
TIME IN MINUTES

Fig. 3



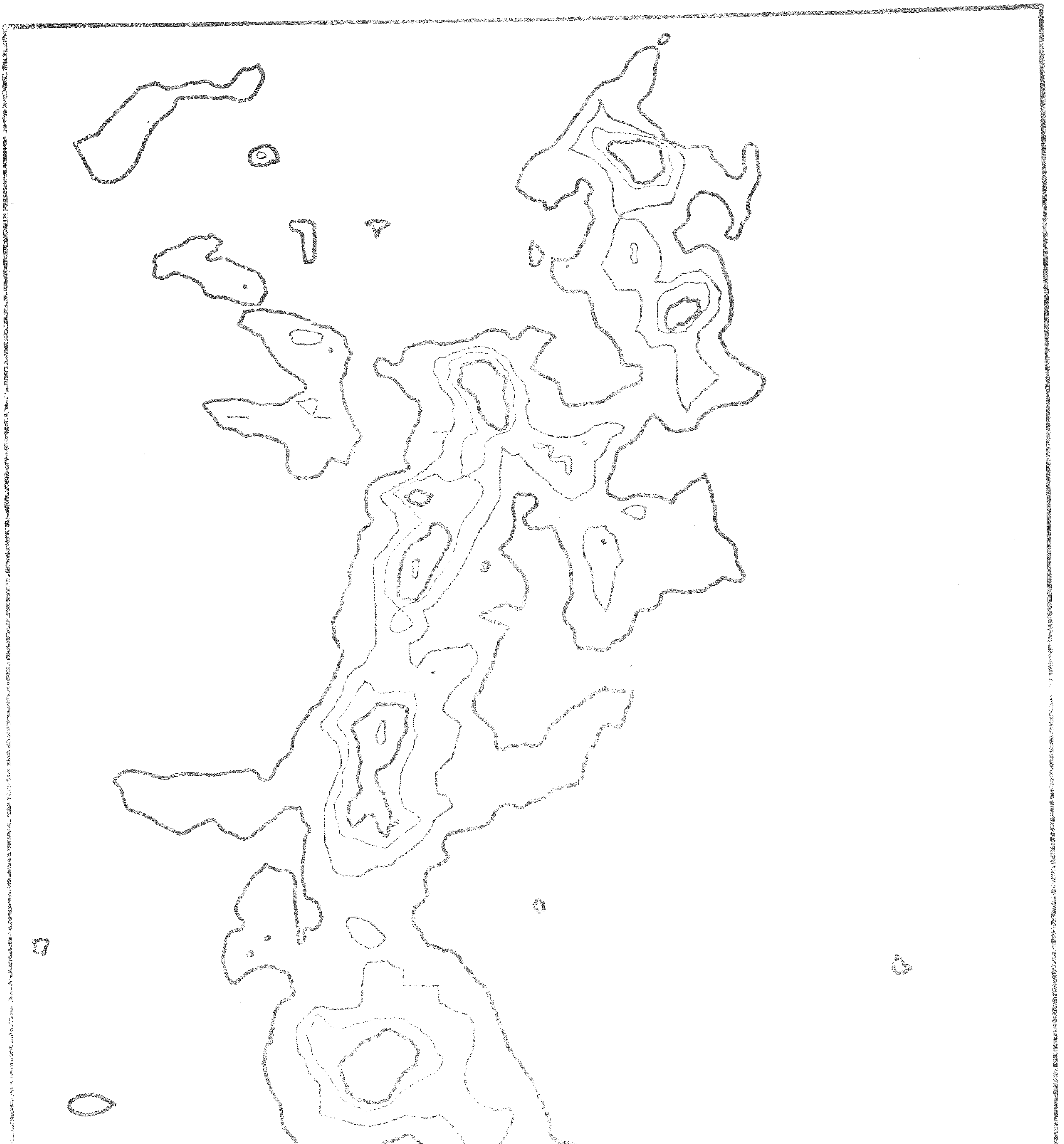


Fig. 5

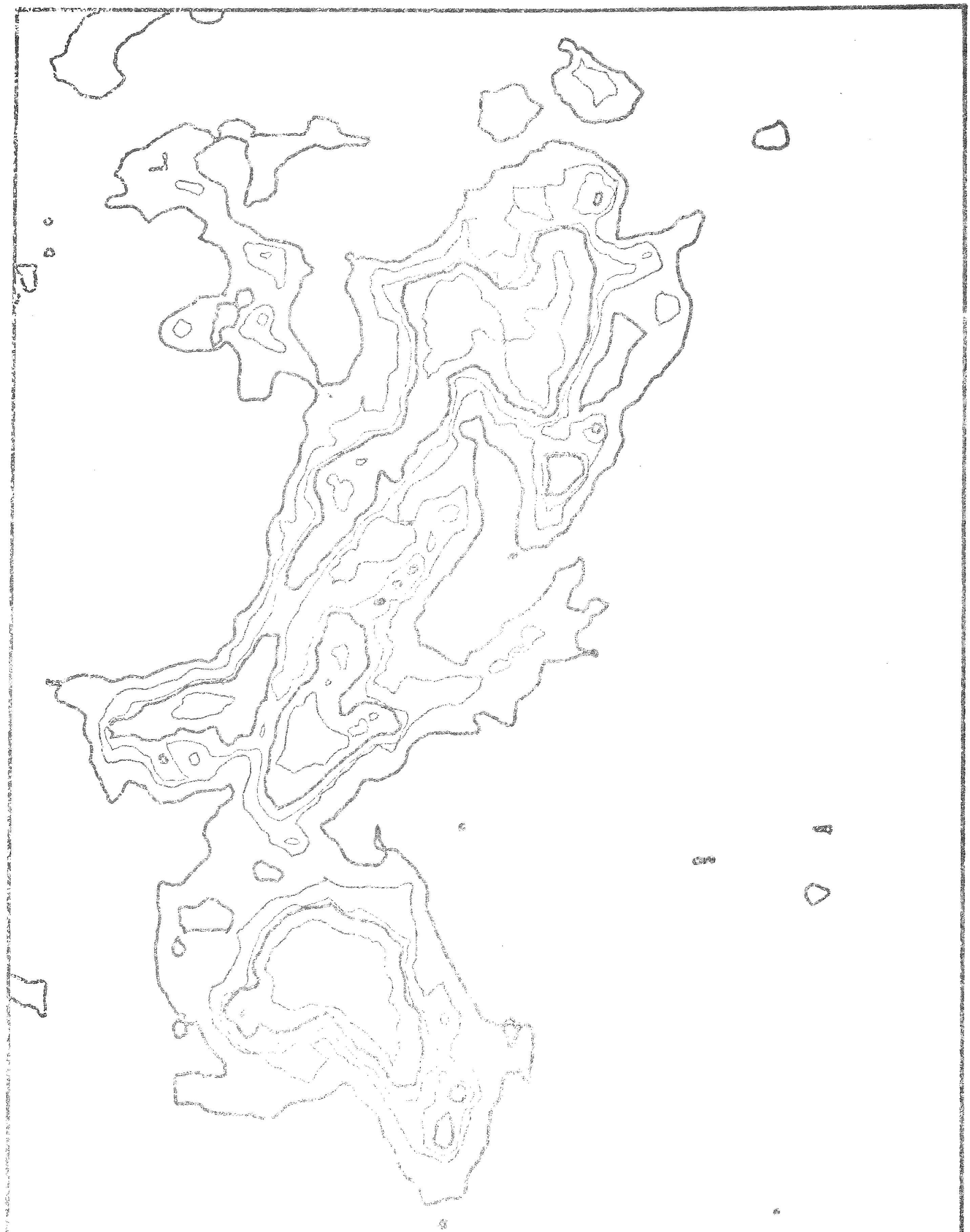


Fig. 7

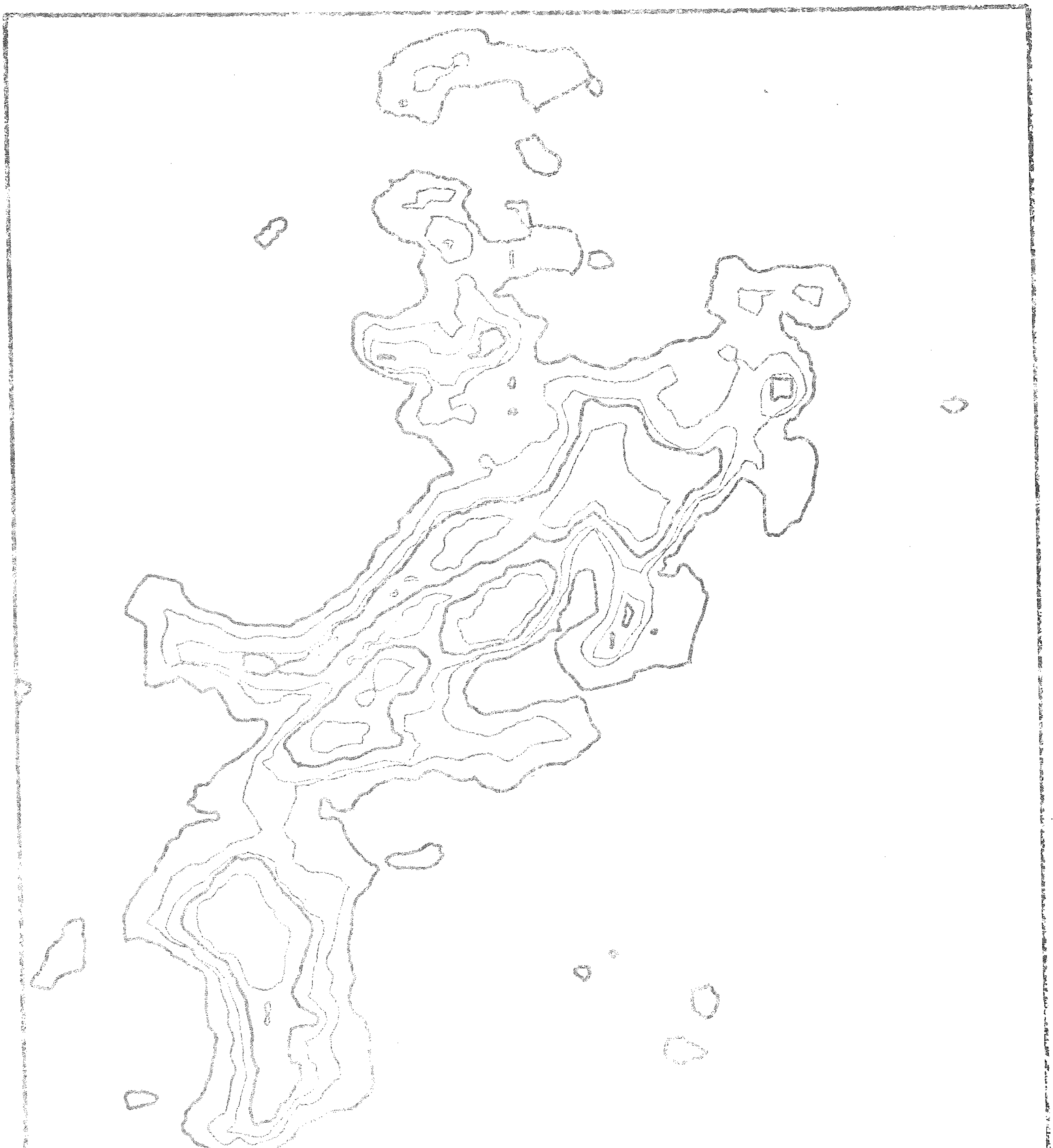


Fig. 8

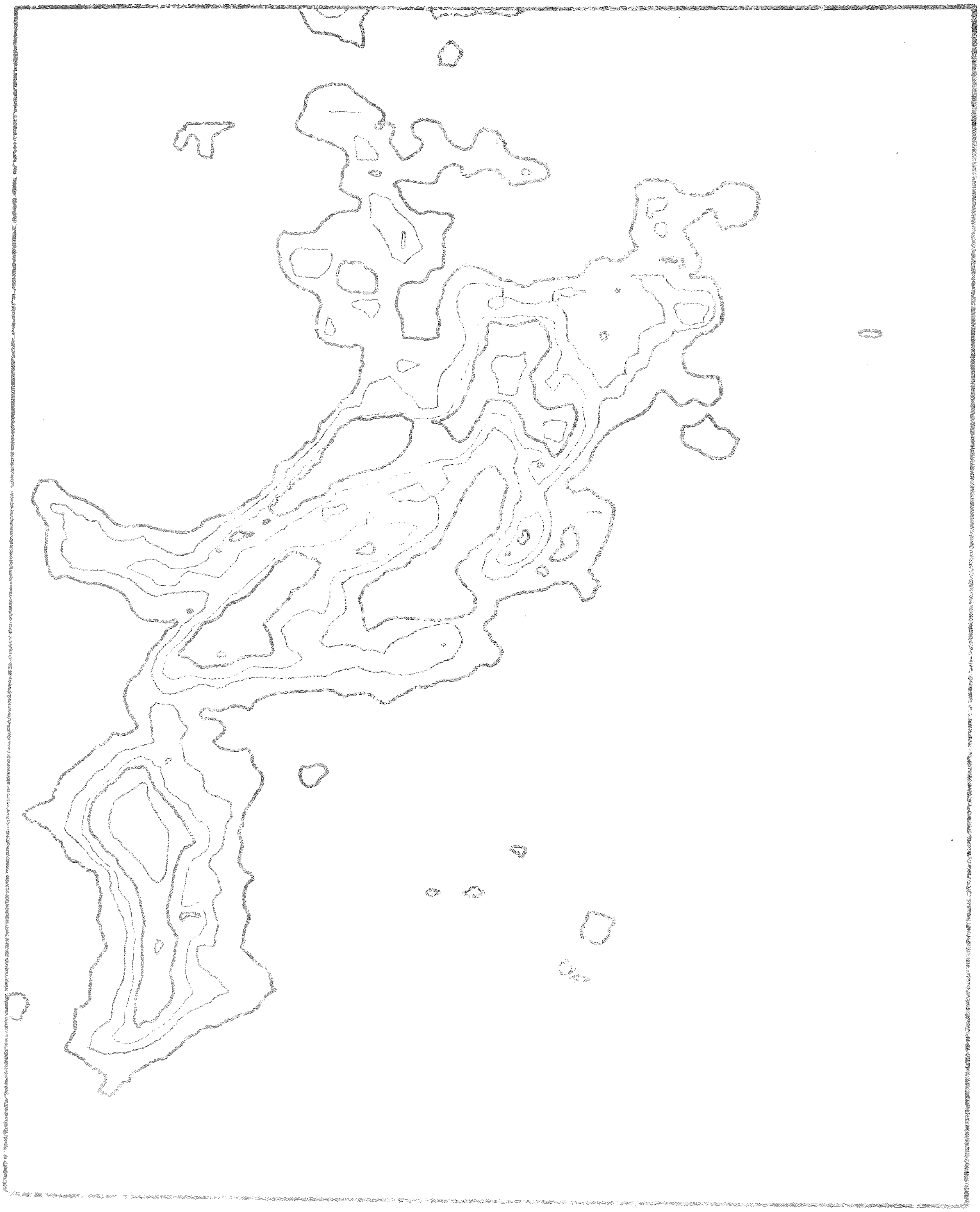


Fig. 9