STRUCTURE AND DYNAMICS OF CONVECTIVE MOTIONS IN THE ACTIVE REGION (JUNE 1984) DURING ITS APPEARANCE AND DEVELOPMENT

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ABSTRACT. This paper presents results derived from line-of-sight velocity measurements in an active region at the time of its appearance and evolution. A network of mass downward flows has been detected. The evolution of the network is studied in detail during the formation and evolution of the sunspots. The role of convective supergranulation cells for the appearance and development of the sunspots is discussed. The observational results lead to the conclusion that the dynamics of the convection observed in the active region during its appearance and development agrees well with a model for magnetic flux emergence from beneath the photosphere, as developed by Parker (1979). A breakdown of the supergranulation convection during the formation of a sunspot penumbra, together with the formation of a toroidal convective cell centered on the spot, seems to indicate there is a dynamical interaction between the convection on the periphery of the spot, treated in Meyer et al's (1974) model, and the convective downward motion of the material within the sunspot flux tube itself, examined in the Parker model (1979). The relationship between these processes, possibly, determines the evolutionary stage and the lifetime of the sunspot.

СТРУКТУРА И ДИНАМИКА КОНВЕКТИВНЫХ ДВИЖЕНИЙ В АКТИВНОЙ ОБЛАСТИ (ИЮНЬ 1984) ВО ВРЕМЯ ЕЕ ВОЗНИКНОВЕНИЯ И РАЗВИТИЯ: В работе представлены результаты измерения лучевой скорости в активной области в процессе ее возникновения и развития. Обнаружена сетка опускающихся потоков вещества. Подробно прослежена эволюция этой сетки при формировании пятен и их развитии. Обсуждается роль конвективных ячеек супергрануляционного размера в возникновении и развитии пятен. Результаты наблюдений приводят к выводу, что динамика наблюдаемой конвекции в активной области в процессе ее возникновения и развития хорошо согласуется с моделю выхода магнитного поля из-под фотосферы, развитой Parker (1979). Нарушение супергрануляционной конвекции при формировании полутени пятна и образование тороидальной конвективной ячейки, центрированной на пятно, указывает, по-видимому, на динамическое взаимодействие между конвекцией по периферии пятна, рассмотренной в модели **Meyer et al.** (1974) и конвективным опусканием вещества в самой силовой трубке пятна, которое рассматривалось в модели **Parker** (1979). Соотношение между этими процессами, возможно, определяет стадию развития и время жизни пятна.

ŠTRUKTURA A DYNAMIKA KONVEKTÍVNYCH POHYBOV V AKTÍVNEJ OBLASTI (JÚN 1984) POČAS JEJ VZNIKU A VÝVOJA. V práci sú uvedené výsledky získané z analýzy radiálnych rýchlostí, pozorovaných počas vzniku a vývoja aktívnej oblasti. Bolo zistené, že v novej aktívnej oblasti prevláda pohyb látky smerom dolu. Látka prúdiaca smerom dolu vytvára sieť a vývoj tejto siete bol detailne študovaný pre obdobie formovania slnečných škvŕn. Diskutovaná je úloha siete konvektívnej supergranulácie pri vzniku a vývoji škvŕn. Pozorovacie údaje vedú k záveru, že dynamika konvekcie pozorovanej pri vzniku a vývoji aktívnej oblasti dobre súvisí s modelom vynárania sa magnetického toku z podfotosférickej vrstvy, tak ako bol vypracovaný Parkerom (1979). Narušenie konvektívnej supergranulárnej siete pri formovaní penumbry škvrny, spolu s vytvorením toroidálnej cely, ktorej stred je totožný so škvrnou, pravdepodobne naznačuje, že existuje dynamická interakcia medzi konvekciou na obvode škvrny (tak ako to plynie z modelu Meyera a i., 1979) a konvektívnym pohybom látky smerom dolu v samotnej tokovej trubici škvrny (podľa Parkerovho modelu, 1979). Vzťah medzi tymito procesmi pravdepodobne určuje vývojový stav a životnú dobu slnečných škvŕn.

1. INTRODUCTION

The question of convection in active regions on the Sun has been and is the subject of animated discussion. The existence of convective cells in the active region was predicted on the basis of the facular network and magnetic field structure on the active region periphery. Our knowledge of the mass motions in the active region is very scanty, especially in regard to the stage of its appearance. Downward motions of mass flows were observed in the region of sunspot formation in pores and smaller spots (Bumba, 1966; Zwaan, 1968; Gopasyuk, 1967; Kawaguchi and Kitai, 1976; Bachmann, 1978). Horizontal motions from the boundary of sunspot penumbrae were detected (Sheeley, 1969; Sheeley and Bhathagar, 1971; Sheeley, 1972).

In this paper we will present some results of line-of-sight velocity measurements in the active region at the time of its appearance and development. Also, we will discuss the pattern of dynamics of material in the active region in connection with magnetic flux emergence and sunspot formation.

2. THE INSTRUMENT AND OBSERVATIONAL DATA

The observations were done with the vector-magnetograph of the Sayan observatory. The principle of operation and the construction have been described by Grigoryev et al. (1985). For measuring the line-of-sight velocities a spectral line Doppler shift compensator at the magnetograph photometer slit is being used. In the past, significant systematic errors were observed in the case of line-of-sight compensators of solar magnetographs, and they were introduced by the balance of two photoreceivers in the wings of a spectral line (Kotov, 1972) as well as by line decentering due to instrumental polarization (Jager, 1972). Our vector-magnetograph employs an electrooptical deflector for alternative measurement of the emission coming from the wings of the spectral line with a single photoreceiver. The system and control of the vector-magnetograph polarization analyzer are such that there is practically no line decentering error due to instrumental polarization (Grigoryev and Selivanov, 1978).

Measurements of all components of the vector of magnetic field strength and line-of-sight velocity were carried out in the 5250.2 Å line of Fe I with a spatial resolution of 2"x4". The observational data on the active region SD 135/1984 covering the time interval from 21 through 26 June 1984 were analyzed. Twenty-one records of this region were obtained; Table 1 lists the times they were taken.

Table 1

List of observed data June 1984.

Date	Coordinates of the region	Time of observ. (UT)
21 June	15S32E	10:55 - 11:30
23 June	16S17E	04:08 - 04:40
		05:30 - 05:54
		05:57 - 06:21
		06-53 - 07-15
		08:06 - 08:26
		09:25 - 09:53
		09:56 - 10:10
		10:20 - 10:49
24 June	16S01W	00:57 - 01:24
		02:22 - 02:57
		03:18 - 03:54
		04:30 - 05:01
		05:04 - 05:35
		06:23 - 06:56
		07:51 - 08:34
		09:44 - 10:16
		10:19 - 10:59
25 June	15S14W	02.42 - 04:16
		05:56 - 06:25
26 June	15S32W	23:53 - 00:21

3. OBSERVATIONAL RESULTS

3.1. General Description of Active Region Development

The active region appeared in an already existing background magnetic field of positive polarity. Our magnetogram of 21 June 1984, at 10:55 UT displays hills of opposite-polarity magnetic field in places where sunspots formed later. The Kitt Peak spatially resolved magnetogram, taken at 15:49 UT, exhibits an enhancement of the magnetic field in a network of positive polarity and the appearance of a magnetic structure of negative polarity on the network boundary.

On the same day (21 June 1984), pores are forming in the failward portion of the region. The Kitt Peak magnetogram of 22 June 1984 already shows a bipolar magnetic region with a strong magnetic field. During that time interval, a following sunspot of the group is forming through magnetg of the pores and the sunspot penumbra starts to form. The leading portion of the region produces a group of pores while the center of the region shows pores with a magnetic field of both polarities. On 23 June, the formation of the following sunspot ends and there appears a well-developed penumbra; around 7 or 8 UT, dopplerograms reveal an Evershed effect in the spot penumbra. In the leading portion of the region, pores and minor sunspots without a penumbra are concentrating.

On 24 June 1984, during our period of observations from 1 to II UT, there occurs merging of the pores and smaller sunspots and the leading spot penumbra starts to form. On 25 June 1984, a well-developed spot group is already observed.

3.2. Mass downward flows in the region of sunspot formation and their time evolution

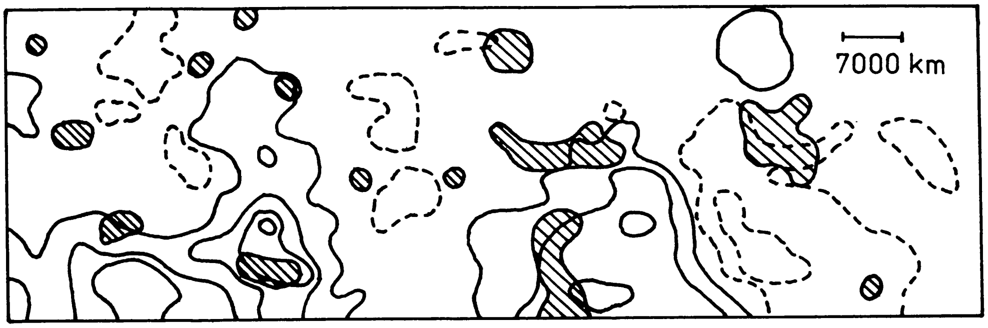

Fig. 1: The map of magnetic field longitudinal component distribution for 21 June 1984 (10:55 UT). The isogauss lines (——— N-polarity, ----- S-polarity) are for 5, 15, 25, and 35 Gs. Shaded areas correspond to places in which material is falling with a velocity of > 0.3 km s^{-1}.

Figure 1 presents a map (for 21 June 1984, 10:55 UT) of the magnetic field longitudinal component of the newly formed active region. On the map, solid lines (N-polarity) and dashed lines (S-polarity) show the isogausses of 5, 15, 25 and 35 Gs. It should be noted that regions of newly formed magnetic structures show mass downward velocities of > 0.3 km s^{-1} which are represented on the map by shaded areas transferred from a dopplerogram.

In order to trace the time variations of the mass downward flows, we have measured the area of downflow regions within the leading and following sunspots outlined by the by the 0.5 km s^{-1} velocity isoline. Figure 2 presents the plotted variations in the area of the downward flow from 21 to 25 June 1984 for the leading sunspot (a solid line) and for the following sunspot (a dashed line). Points there represent the values averaged over several dopplerograms during a day. It is evident that the downward flow area for the following sunspot increases 20-fold from the appearance of the first pore on 21 June 1984 to the development of the sunspot with a penumbra. Following the development of the penumbra and the appearance of the Evershed effect, the downward flow began decreasing in area on 23 June 1984.

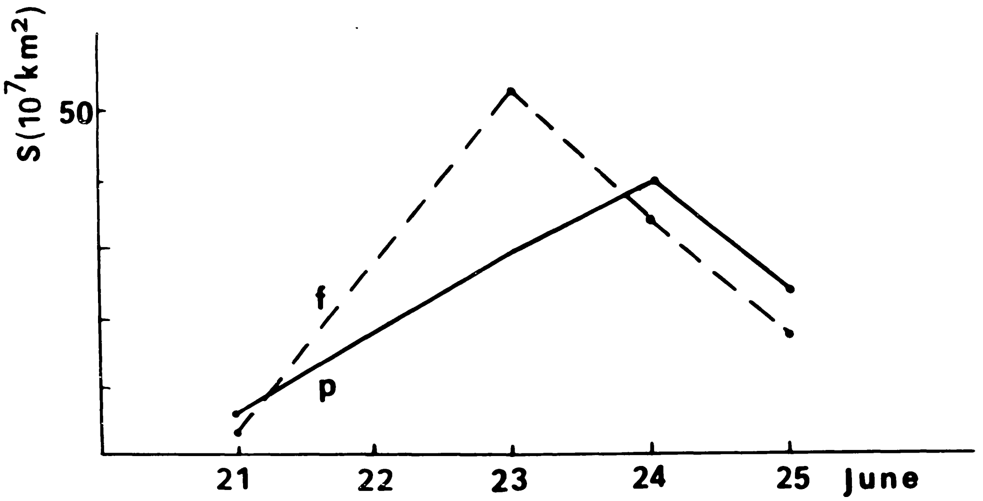

Fig. 2: The variations in the area in which the material is observed to fall with a velocity of $\geqslant 0.5$ km s^{-1} in the active region from 21 fo 25 June 1984.

The similar character of variations of the mass downward flow is also observed in the leading sunspot. The downward flow increased in the area 7-fold from 21 to 24 June 1984 and began decreasing after the penumbra has formed.

The upper part of Figure 3 shows analogous plots of the downward flow area variation throughout the day for 23 and 24 June 1984 and the lower part shows the variations in integral magnetic flux F (crosses) and integral magnetic field strength B (continuous trace). The integral magnetic flux was measu-

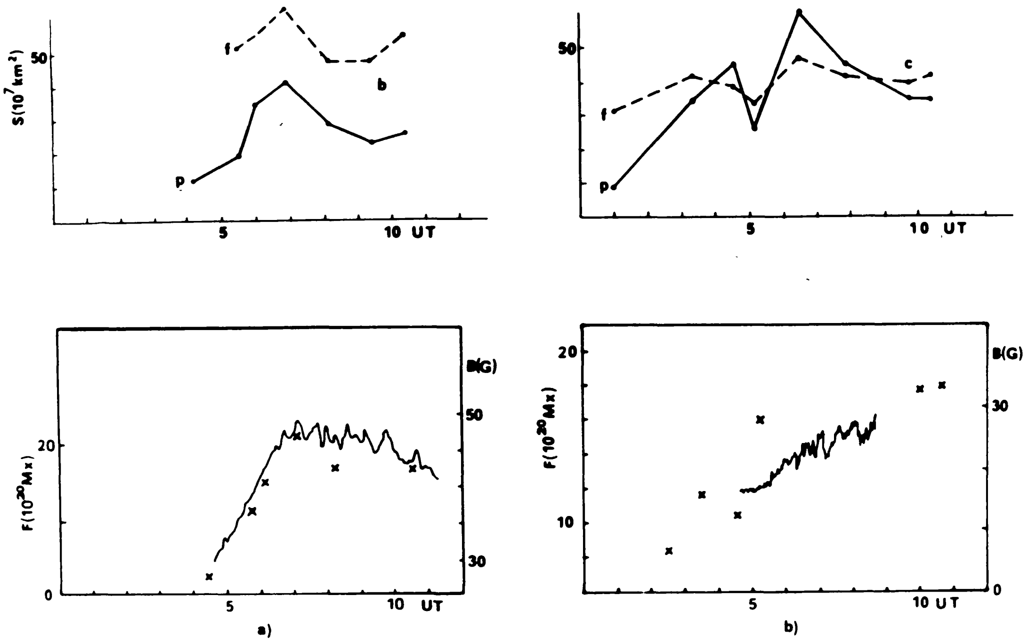

Fig. 3: The variation in the area occupied by the mass down flow with a velocity of $\geqslant 0.5$ km s^{-1} and in magnetic flux in the region of the leader (P) and following (f) sunspots for 23(a) and 24(b) June 1984.

red using magnetograms of the magnetic field longitudinal component and is the difference of the magnetic fluxes of N- and S-polarities, i.e. $F = F_N - F_S$. The integral magnetic field strength was recorded by M.L. Demidov with the magnetograph of the solar telescope for operative predictions (a description of the instrument was given by Grigoryev et al. (1982) and Grigoryev et al. (1983)); this quantity represents the magnetic field strength measured from the entire active region. This was achieved through defocusing the image at the spectrograph entrace slit so that the resolution was a circle 170" in diameter for 23 June 1984 and 250" for 24 June 1984. Obviously, there is good agreement in the behaviour of changes in the area of the downward flow and magnetic flux variation as well as a coincidence of their maxima around 7^h on 23 June and 60:30 on 24 June 1984.

An inspection of $H\alpha$-filtergrams reveals that the rapid increase in integral magnetic flux on the interval 4^h - 6^h was accompanied by a massive appearance of a system of arch-like filaments in the central part of the active region.

3.3. Cellular structure of the downward flow network in the active region.

Figure 4 presents active region dopplerograms for 23 June 1984, 05:30 - 05:54 UT, 05:57 - 06:21 UT and 10:20 - 10:49 UT, for 24 June, 03:19 - 03:54 UT

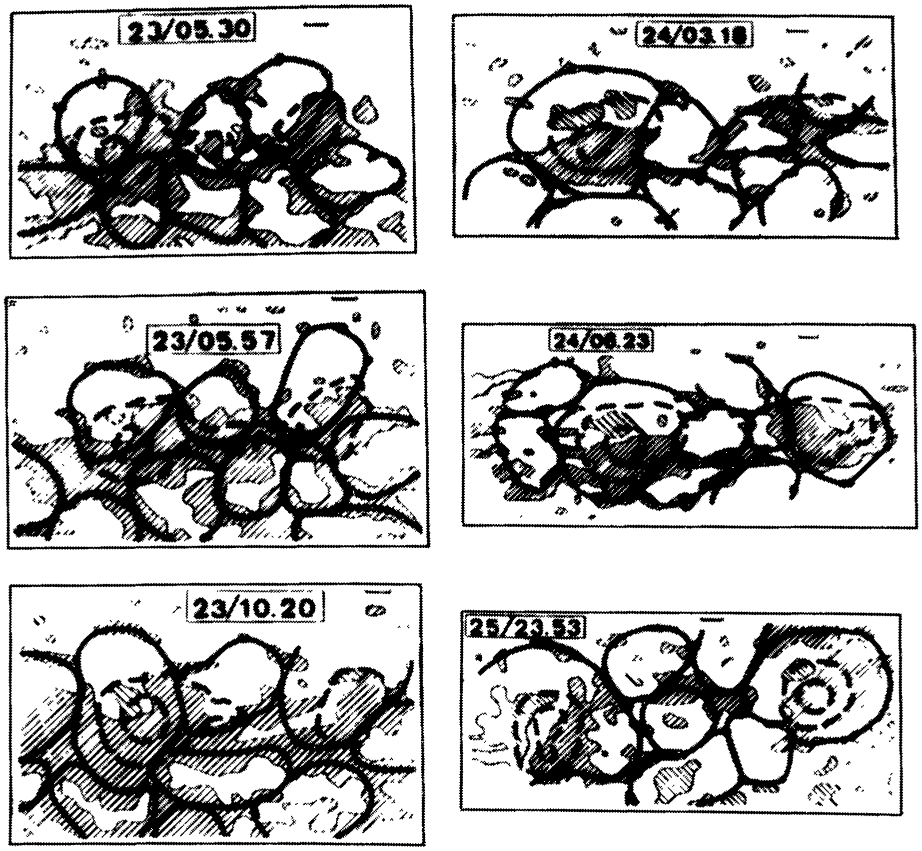

Fig. 4: Dopplerograms of the active region for the time interval 23-26 June. 0.3 km s^{-1} velocity contours are outlined. Shaded areas within the contours, hatched at 45°, corresponds to down flow while those hatched at 135° correspond to upflow of the material. Thick dashed lines mark the position of the sunspot umbrae and penumbrae. A bar in the upper corner at the right of each map corresponds to the angular size of 10". Thick solid lines schematically show the cell structure of the falling mass flow.

and for 25 June, 23:53 - 00:21 UT. First of all, it should be noted that the dopplerograms clearly show ring-shaped structures of a descending flow. To avoid encumbring the figures, we have shown only the contours of flow regions corresponding to a velocity of 0.3 km s^{-1}. Shaded areas inside the contours at 45° correspond to downward flows and at 135° to upward flows. Heavy dashed lines are the isophotes making up 0.5 and 0.9 of the mean intensity of the surrounding photosphere, which in the first approximation corresponds to the location of the sunspot umbra and penumbra. A segment at the upper corner to the right of each map corresponds to the angular dimension of 10". Heavy solid lines schematically show the cell structure of the downward flow. These lines are drawn according to the maxima of downward velocity. Although the line-of-sight velocity measurements may be substantially affected by the 5-minute oscillations which have a significant amplitude in the photosphere, the comparison, however, of the dopplerograms for 23 June 1984, 05:30 and 05:57 UT shows that the identification of downward flow cells is quite confident. The size of the cells is, on an average, equal to that of supergranulation cells.

Analysis of the temporal variations in the cell structure has shown that in the early stage of spot appearance and enhancement of its magnetic flux, the spot lies on the boundary of neighbouring cells of a downward flow. The downward velocities in the region of sunspot formation are as high as 1.5 km s^{-1}. On 23 June at 05:30 - 05:54 UT, the sunspots, both leading and following, are situated on the cell boundary. Mass downward motion persists during some period, seemingly not longer than one day after the penumbra begins to form. This is because the velocity maps show no distinct change of sign of the line-of-sight velocity in the sunspot penumbra characteristic of the normal Evershed effect.

Line-of-sight velocity structure characteristic of the Evershed effect, is produced within a certain period of time after the penumbra appearance. This is traceable best for the leading sunspot. The dopplerograms of 23 June and until 10 UT on 24 June 1984 all show no distinct substantial signatures of the appearance of line-of-sight velocity in the sunspot penumbra typical of the normal Evershed effect. It should be noted, however, that in that period the active region was located close to the central meridian. However, the following sunspot region shows a large (in magnitude) velocity component "from the observer" and a small one "toward the observer". This effect for the leading sunspot is appreciably weaker. In addition, the structure of mass downward flow cells in the leading sunspot region on 24 June 1984 showed that until 10 UT the sunspot was located on the cell boundary. By the end of the observation interval on 24 June, the cell structure in the leading spot region became disordered and a ring of descending material started to form around the leading sunspot. The dopplerogram of 25 June 1984, 23:53 - 00:21, already shows a well-developed ring-shaped structure of mass downward flow around the leading spot.

The same such ring-like structure of downward flow had formed around the following sunspot as early as 23 June 1984.

The formation of such a ring structure occurs nearly simultaneously with the appearance of the well-developed penumbra and of a structure of Evershed motion in it.

4. DISCUSSION

4.1. Network of convective cells in the active region.

The results of our observations indicated the existence in the active region of a network of mass downward flows with the size of the cells close to that of supergranules. It is natural to regad this network as the manifestation of convective supergranulation motions in the active region.

The comparison of our dopplerograms with those of the longitudinal component of the magnetic field vector as well as with Kitt Peak magnetograms shows a good coincidence of the downward flow network with the magnetic network. This is especially well seen in a number of earlier records covering the initial phase of active region development when the supergranulation network was considerably enhanced. On the periphery of the active region, the nodes of the downward flow network coincide nicely with flocculi identified from H_{α} - filtergrams.

4.2. Mass downward flow and magnetic flux emergence into the photosphere

The appearance of an active region is signalled by an enhancement of the magnetic field in the magnetic network nodes. The main, enhanced magnetic structures of both polarities are located roughly in the same places in which the leading and following sunspots are developing afterwards. The distance between the main magnetic structures exceeds the size of the supergranulation cell at the initial moment of time when the appearance of a new active region is detected. We would like to emphasize once more these two factors in the earliest stage of active region appearance: 1/ the appearance of magnetic field hills on the network boundary, and 2/ their appearance not within the same supergranulation cell for two reasons.

Firstly, not all of the investigators obtained the same result on the place where sunspots occur with respect to the supergranulation cell. Simon and Leighton (1964), by studying the relationship of sunspots with supergranulation, found that the well-developed sunspot has a tendency to be located at the center of the supergranulation cell. Later on, it was shown that the initial process of emergence of new flux of the active region occurs on the network boundary and the sunspot as it is evolving may occupy the entire cell (Bumba and Howard, 1965; Bumba et al., 1968; Bappu, Grigoryev and Stepanov, 1968). Born (1974), by studying newly emerged active regions, demonstrated that they form solely on the chromospheric net boundaries. A contrary result was obtained by Harvey and Matin (1973).

Secondly, until presently the question of the mechanism for active region magnetic flux emergence has been discussed. Following the pioneering paper of Cowling (1946) who concluded that magnetic flux of a sunspot group emerges from beneath subphotospheric layers, and a paper of Parker (1955) who proposed as the flux emergence mechanism magnetic buoyancy, much observational work was done in support of this basic statement that the magnetic field of an active region is not generated in the photosphere but emerges from deeper layers (Vitinsky and Ikhsanov, 1964; Bumba and Howard, 1965; Bappu, Grigoryev and Stepanov, 1968; Gopasyuk, 1967; Born, 1974; Grigoryev and Ermakova, 1976; Ermakova, 1982; Ermakova and Kotrč, 1979). On the other hand, since the appearance of a paper by Simon and Leighton (1964), the role of supergranulation motions for magnetic field concentration and sunspot formation has been widely discussed. A large number of observed phenomena, at first glance, leads to the view that supergranulation convection is directly involved in the emergence and concentration of sunspot magnetic fields (see, e.g. Bruzek, 1967; Harvey and Martin, 1973; Frazier, 1972; Born, 1974). A model of local flux concentration by supergranulation is advocated by Meyer et al. (1974; 1977). They appeal to such a picture in which magnetic flux loops emerge near the supergranule center and are, then, displaced toward the boundaries due to horizontal flow. This suggestion disagrees with observations reported by many authors (Harvey and Martin, 1973; Zirin and Tanaka, 1973; Born, 1974; Glackin, 1975; Worden and Simon, 1976).

Our observational results indicate that although the magnetic flux tube footpoints emerge in the photosphere on the supergranulation network boundary, the places where the field is enhanced in a quite conspicuous manner, are already at a distance far exceeding the supergranule size, that is ~ 65000 km. It is in these places where the leading and following sunspots of the active region both appear. Thus, our observations are most likely to favour the view that there emerges a system of individual magnetic flux tubes which are not yet tightly packed together but already show a tendency to merging together. They might acquire this tendency as they pass through the convection zone. Such a picture is consistent with the main ideas underlying the Parker model (1979). In this model the mass downward flow serves as the main component required for magnetic flux tubes to come closer together. Observations reported by various authors have documented excellently this view.

Gopasyuk (1967) was the first to show, using observations of small, short-lived active regions, that "as early as before a sunspot appears, there arise velocities in both the photosphere and the chromosphere which indicate that the material is inflowing into the location of sunspot appearance". He also pointed out that at the time the sunspot appears the velocities slightly increase and persist for a rather long time following its appearance. The greatest downward velocity of the gas in the photosphere is roughly 1 km s^{-1}. In an earlier paper Bumba (1966) examined the velocities in fourty minor spots and pores with the result that the gas either comes down or inflows into the sunspot. Mass downward motion was also reported by Zwaan (1968). It is also known that a downward velocity of 0.5 km s^{-1} in an active region, in general, was established by Giovanelli (1970).

During the early stage of active region development, a downward velocity field was discovered by Kavaguchi and Kitai (1976). In faculae and the quiet network the magnetic field is also associated with persistent downward motion (Frazier, 1974). Bachmann (1978) has also found from magnetographic observations a downward flow of the gas in the region of a strong magnetic field. The greatest downward velocity was observed in main sunspots of the leading and following parts of the sunspot group.

Thus, our observation of the enhancement of a mass downward flow with increasing magnetic flux at the photospheric level (as shown in Figure 3) is quite important for modelling the magnetic flux emergence from below the photosphere.

4.3. Convection in the active region: Formation and stability of sunspot.

We want to emphasize once again that mass downward motion at the site of sunspot formation is detectable in the earliest stage of magnetic field enhancement in the magnetic network, and the amplitude of downward velocity increases with increasing magnetic flux of the sunspot. At the same time, the well-developed network of cells of descending material covers the entire active region and sunspots are forming on the cell boundaries, i.e. in the supergranulation network nodes. Then, as the sunspot grows and a penumbra is shaping up, the convection structure at the sunspot breaks down. This occurs some time after the penumbra forms (not later than 24 hr). Around the spot, a ring of descending material starts to form, and it would not always be a closed one, especially on the side facing inward the active region. The distance between the penumbra boundary and the descending material ring reaches 20000 km. By that time, an Evershed flow is set up within the sunspot.

A number of authors, e.g. Sheeley (1969; 1971; 1972), Vrabec (1971) and Harvey et al. (1971) discovered, around the spot in the facula-free photosphere, horizontal flows with velocities between 0.5 and 1 km s^{-1} at distances from 10000 to 20000 km. These horizontal flows in a superpenumbra differ greatly in their flow structure and velocity amplitude from Evershed flows. On magnetograms such cells are also observed as a "moat" in the magnetic field structure nearby the sunspot. The sunspot finds itself surrounded by a ring of enhanced magnetic field at some distance from the penumbra. Therefore such cells were named the moat-cessl. Moving magnetic features were found in the region of moat-cells (Harvey and Harvey, 1973).

These phenomena, viz. the descending material ring around the sunspot, horizontal motions in the superpenumbra, and the "moat" in the magnetic field around the sunspot, all indicate the similarity with supergranulation and as such they imply that the sunspot tends to occupy the center of the supergranule. However, bearing in mind the dynamics of development of the sunspot and convective motions in the active region, as described earlier in this text, we arrive at the conclusion that a convective cell of a different type, i.e. differing from the usual supergranulation cell, is formed around the sunspot. It is most likely reminiscent of the toroidal, convective moat-cell around the spot, treated in the Meyer et al. (1974) model.

In this model the moat-cell carries out the flow of a decaying sunspot away during several days. If, however, the flow is a smooth, vertical one, then flow affects little the tube and the sunspot will be decaying slowly.

A weak point in the Meyer et al. (1974; 1977) model is represented by the process of concentration of magnetic flux tubes by supergranulation convection as well as by constriction and stabilization of the sunspot magnetic flux through dynamic pressure of the surrounding convective, upward flows. Parker (1979) proposed a convective, descending flow in a fluid devoid of field between the magnetic flux tubes to be additional dynamic forces for collecting newly emerged magnetic fluxes and stabilizing, then, the sunspot below its fan-shaped portion. The downward flow of fluid, on the one hand, as has already been mentioned, is an inevitable companion of any emerging flux tube. On the other hand, the emergence and enhancement of a new magnetic flux occur on the supergranulation cell boundaries where there is already a downward motion of fluid: and finally, the very cooling of fluid inside the flux tube stabilizes the downward flow of fluid (Parker, 1979).

Thus, the mass downward motion we observe at the site of sunspot formation is in good agreement with the views of sunspot formation developed by Parker. However, after the penumbra is formed, we observe the formation of a ring of descending material around the sunspot. This, together with a number of the above-mentioned phenomena indicates the formation in this stage of a convective cell described in the Meyer et al. (1974) model. In consequence, around the spot nearby the main flux tube there must exist mass upward motion which ensures the horizontal motion of the material in the superprenumbra and the descending motion in the ring-shaped region around the spot. This, we believe, does not contradict the mass downward flow in layers beneath the sunspot in between the individual flux tubes which form the main flux tube. In his model Parker also emphasized that the upward motion on the sunspot periphery and the downward flow inside the sunspot can co-exist. The downward flow in the sunspot may happen to be a parial counterflow with respect to the upward motion of fluid. Both types of flow serve as a sink of heat which is accumulated above the sunspot. In Figure 5 we thus present a possible scheme of motions.

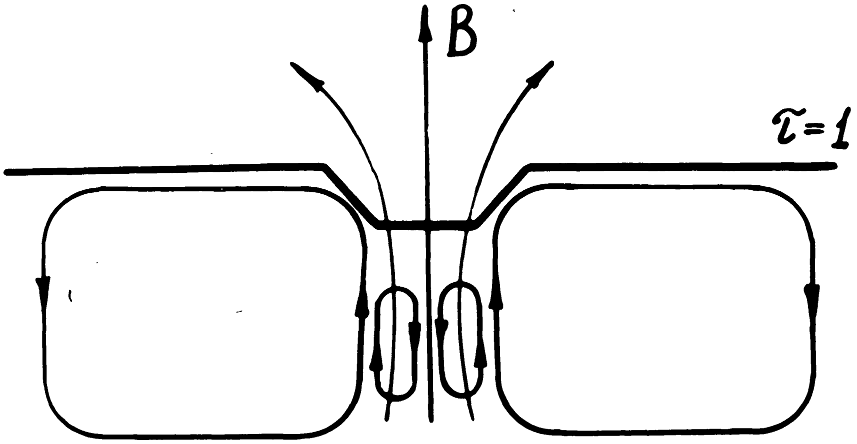

Fig. 5: A schematic of mass convective motion in the region of a mature sunspot.

The existence of a toroidal convective cell around the sunspot together with the downward motion in between the flux tubes in the sunspot removes such difficulties in the Meyer et al. (1974) in which the moat-cell was able to lead rather quickly to a decay of the sunspot. Whereas observations indicate that the moat-cell always accompanies long-lived, slowly decaying sunspots.

It is likely that the growth, stable existence and size reduction of the sunspot are determined by a dynamical interaction between the convection on the sunspot periphery and the convective downward motion of material in the sunspot itself. The relationship between these processes, possibly, determines the evolutionary stage and the lifetime of the sunspot.

5. CONCLUSIONS

The main results of this study may be summarized as follows.

1. Magnetic flux of a newly formed active region emerges at the supergranulation network nodes. The main magnetic features are anhanced at places where later on the main sunspots of the group are formed. The distance between these magnetic features exceeds the size of a supergranulation cell.

2. The region in which magnetic flux emerges and sunspot are formed afterwards shows mass downward flows with velocities of $\gtrsim$ 0.5 km s^{-1}. The downward motion is enhanced covering an ever increasing area as the sunspot is forming and its magnetic flux is being anhanced. The downward velocity reaches 1.5 km s^{-1} and persists some time after the penumbra is formed but not longer than 24 hr.

3. During about 24 hr there is occurring a unified process of threee interrelated phenomena: 1/ formation of the well-developed penumbra of the sunspot; 2/ breakdown of the usual convective supergranulation cells in the region of the evolving sunspot and formation around it of a toroidal convective cell; and 3/ establishment of an Evershed flow in the sunspot.

4. The dynamics of observed convective motions in the active region during its appearance and development is in good agreement with the model of magnetic flux emergence from beneath the photosphere developed by Parker (1979).

5. Breakdown of the supergranulation convection during the formation of the sunspot penumbra and the formation of a toroidal convective cell centered on the sunspot seem to indicate there is a dynamical interaction between the convection on the sunspot periphery through the moat-cell treated in the Meyer et al. (1974) model and the convective downward motion of the material within the sunspot flux tube itself considered in the Parker (1979) model. The relationship between these processes, possibly, determines the evolutionary stage and the lifetime of the sunspot.

Acknowledgements. We are indebted to Dr Livingston for supplying Kitt Peak magnetograms and to Dr Kurokawa for Hα-filtergrams from the Hida observatory.

Further thanks are due to SibIZMIR workes who assisted in obtaining observational data, especially to B.F. Osak and M.L. Demidov as well as to colleagues for helpful discussions. We are grateful to V.G. Mikhalkovsky for his

assistence in preparing the English version of the manuscript and for typing the text.

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