PREFACE AND INTRODUCTION

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The present symposium, to my knowledge the largest ever held in the field of solar research (170 astronomers from 21 countries) was held in the building of the Hungarian Academy of Sciences in Budapest from September 4 to 8, 1967. It was the 35th symposium organized and sponsored by the International Astronomical Union. The majority of participants were financed from national sources. The Organizing Committee consisted of K. O. Kiepenheuer (Chairman), L. Davis, L. Dezső (Local Organizer), A. D. Fokker, R. Michard, A. B. Severny, H. J. Smith, Z. Švestka, and H. Tanaka.

In order to ensure prompt publication, the manuscripts had to be supplied by the authors 1 month after the meeting. The discussions have been recorded on tape. Their reproduction in this book, however, is based almost completely on the contributors' writing down their comments and questions on the spot.

Two special projects have been reported and discussed shortly during the symposium:

The world wide project 'Cooperative Study of Solar Active Regions' (CSSAR) organized by Dr. R. Michard, under the auspices of the IAU, which has put at the disposal of our solar community a precious observing material on Active Regions over a period of 6 months.

The 'Proton Flare Project' (PFP), organized by P. Simon and Z. Švestka, which concentrates on single Active Regions having produced a proton flare, and which tries to supply as much information as possible on the structure and development of these special regions.

Both projects are model cases and exceedingly valuable also for the general understanding of Active Regions.

The subjects of the sessions were the following: General Development of an Active Region (Chairman: R. B. Leighton); Theoretical Aspects (L. Davis); Optical Structure of an Active Region (J. W. Evans and A. B. Severny); Cooperative Study of Solar Active Regions, CSSAR (Z. Švestka); Coronal and Interplanetary Structure of an Active Region, Transient Phenomena (G. Righini); Proton Flare Project, PFP (V. A. Krat); Radio Structure of an Active Region (H. Dodson-Prince).

Summaries for each session were given on the morning of the next day by: R. Howard, H. U. Schmidt, N. Sheeley, G. Newkirk, A. Bruzek, and A. D. Fokker. They are not included in the proceedings because of their provisional character. The diffi-

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cult and delicate task of presenting an overall summary at the end of the symposium was brilliantly solved by C. de Jager (see p. 602).

In addition to the scientific sessions there was a full-day excursion to the Balaton Lake. A banquet in the Citadella was offered to all participants by the Academy. Excursions, meeting rooms, ladies' program, and other activities were splendidly arranged by the local committee which was in the hands of the inexhaustible Dr. L. Dezső, Debrecen. We have to thank him and his staff very much.

I further want to express my sincere gratitude to the members of the Organizing Committee, especially to Dr. Z. Švestka for all his kind assistance from the beginning to the end; to Mrs. H. Siebler-Ferry and Miss M. Ilan for valuable help editing the manuscripts and the discussions, as well as to Mrs. H. Neuzilova and Dr. Bruzek for their kind help during the symposium.

And now let me turn right away to the subject of our symposium: As you will agree, an Active Region (AR) on the Sun is a beautiful one with all its spectacular events in photosphere, chromosphere, and corona. A challenge to the optical observer, a unique and inexhaustible paradise for the investigator of the interplay of magnetic fields, turbulence, hydromagnetics, and radiation in a stellar plasma! An Active Region on the Sun is also a very complex and intriguing phenomenon of solar meteorology, which shows a different aspect almost in every wavelength we look at it, X, EUV, visible, infrared or radio. Apart from the many people working on certain features occurring within an Active Region – as spots, flares faculae, prominences – and their terrestrial effects, there are really rather few, strictly investigating the structure and the development of an Active Region as a whole. The more we are happily surprised about the great number of attendants and contributors to this symposium.

What is an Active Region or a Center of Activity? According to D'Azambuja (1953) it is "the totality of all visible phenomena accompanying the birth of sunspots". Today we should extend this definition a little bit: "The totality of all observable phenomena preceding, accompanying and following the birth of sunspots, incl. radio-, X-, EUV- and particle emission." The Active Region comprises photospheric, chromospheric and coronal features and reaches practically into interplanetary space.

Physically speaking, the observable part of a single Active Region represents only a very small fraction of a much larger machinery which produces the solar cycle and which has been built together so convincingly by Babcock (1963). We know nowadays that this model does not cover all observational aspects of a solar cycle. It is to be expected that at least the field-amplification mechanism and its dependence upon latitude needs adaptation to the new observations of Bumba, Dodson, Hedeman, and Howard, presented during this symposium. It will be indispensable during this symposium – from time to time – to refer to this large-scale mechanism, in order to penetrate with our imagination into the non-observable parts of the solar interior, to reach the roots of the Active Regions.

The most primary *observable* components of an Active Region lie down in the photosphere. For this reason our most primary information will be optical and comes from the visible part of the spectrum. Only in this region a reasonable angular resolution can be obtained and magnetic fields can be measured with some accuracy.

The synopsis of an Active Region is impeded moreover by the great diversity of the involved phenomena as well as by the great number of instruments needed to observe them in the different layers of the solar atmosphere. Last not least – also because of this diversity – the understanding between observers and theoreticians, in this case mostly hydromagneticians, needs definitely to be improved. Let us hope that this symposium will work in this direction.

During this meeting we will probably be tempted again and again to get caught too much by a single interesting phenomenon as perhaps flares, instead of doing our best to find out about the large and simple laws governing the development of an Active Region as a unit. On the other hand we must be aware of the fact that, in spite of an Active Region developing to sizes of considerably more than 100000 km, small-scale events with almost subtelescopic dimensions are of crucial importance. I think of the initial formation of a magnetic region, of a magnetic pore, or of the random-walk mechanism. The limits which are set today to the angular and time resolution of sensitive magnetographs are indeed a serious handicap for the study of the basic processes forming an Active Region. However, good chromospheric filtergrams and spectroheliograms in Hα have proved already helpful, supplementing magnetograms with a kind of high-resolution magnetic vectorgrams (filamentary structure of disturbed chromosphere), in K (Ca II) they represent sensitive indicators for the very first occurrence of field concentration. Also the optical observation of large filaments (on the disk and on the solar limb) as well as of moustaches will tell us about high-resolution details in the magnetic field, which are not in the magnetograms. I am convinced – even knowing that this is a complicated project – that it would pay to bring a magnetograph in the stratosphere or even in space. Studying Active Regions, one is somehow in the difficult position of a man who has to investigate the development of an elephant with a microscope!

Fortunately the whole phenomenon of an Active Region – thanks to a number of important new observations and a significant progress in their hydromagnetic interpretation – has become more transparent, more intelligible during the last decade. I draw your attention to the concept of supergranules, which together with the observations of Leighton (1964), Bumba and Howard (1965) and others that magnetic fields and spots initially appear along the boundaries of adjacent supergranules, has changed drastically the model of an Active Region. Moreover, Leighton's random-walk diffusion, the systematic analysis of magnetic metamorphosis of an Active Region by the Babcocks, Bumba and Howard (1965), Severny (1964) and others using especially the wealth of full-disk magnetograms obtained at Mt. Wilson Observatory have become the most important part of today's model of an Active Region. Just as important,

however, are the many theoretical attempts by Sweet (1956), Dungey (1958), Gold and Hoyle (1960), Parker, Petschek (1963) and others, which have been made in the domain of hydromagnetics somehow with the aim to lower the barriers built up by the concept of the frozen-in magnetic field with its much too long time scale. This type of work has mostly been carried out in connection with the magnetic interpretation of flares. We are now allowed again, as in good old times and as in our laboratories, to reconnect field lines, to concentrate or to dilute magnetic flux in the solar atmosphere somewhat quicker again. And last not least, I would like to stress again how strongly Babcock's large-scale magnetic mechanism of the solar cycle has stimulated and influenced last years' work on Active Regions, even if it might turn out necessary to modify it in some respects. I think we are quite lucky to start our symposium with such fertile boundary conditions.

I will not try to give the story or a description of an Active Region here, but let me just recall a few important facts to which we should not forget to direct our attention. We know today for sure that the process producing and structuring an Active Region is of magnetic nature and that all the accompanying features like spots, faculae, flares and associated effects, filaments etc., are byproducts of this magnetic process. Therefore our responsibility must be first of all to analyse and to interpret this process. The first sessions will be mostly devoted to this problem and Messrs. Bumba, Howard and Schmidt have kindly accepted to review shortly the actual situation in this field of research.

An important part of this magnetic process – which is not just easy to observe – goes on under our eyes. Another part, which we will never be able to follow, happens inside the Sun. Concentrating on the observable part, we can at least hope to be able to define clear boundary conditions for the unvisible interior.

What we observe is that – preferably in a region with a weak residual magnetic field, left over from old Active Regions – a very sudden local increase of magnetic flux of the order of 10^{21} Maxwell within a few tens of hours occurs. The way of growing, the structure and the configuration of this field, which is reflected quite in detail by the brightening in the K line (Ca II), as well as the initial spot formations are related so closely and in such a detail to the granules and supergranules, that it is very difficult to think that the spot field or the initial field of a BM-region is not being produced or concentrated by the supergranules themselves. Very remarkably also are the close analogy between the birth of a pore in closest interaction with one or a few granules (Schröter, 1962; Bray and Loughhead, 1964) and the formation of a spot group or a BM-region in a just as intimate contact with one or a few supergranules (Bumba and Howard, 1965).

One has to keep in mind, however, that observation shows quite clearly that – at least during the active phase of the birth of an Active Region – the old magnetic field even in the very surrounding of the Active Region's birth place does not change. This means, that the magnetic flux of a young Active Region cannot just simply be the

flux of the visible photospheric surrounding. It must come from some depths below the photosphere.

All these observations in combination with some recent results by Parker (1963), Weiss (1966) and others about the concentration of magnetic flux by turbulence in the deep convective zone as well as in higher levels along the boundaries of supergranules make it appear quite promising to discuss the formation of sunspots as occurring *almost in situ* in the photosphere. Sheeley's (1967) observation of strong local magnetic fields outside the spot belts points in the same direction. Mr. Schmidt and Mr. Weiss will talk about this important subject. In any case more reliable informations have to be collected to get a better idea of the height or the depth in which these flux concentrations originate. A study of the metamorphosis of the supergranules in the course of hours and days will probably be of great help in this connection.

Even if the total magnetic flux constituting an Active Region is being concentrated from a quasi-superficial flux by the supergranular convection, still the cooperation of a well-organized deep-seated large scale field is indispensable. We all know that the 11-year variation in the sunspot numbers, the Spörer law of variation of mean latitude of sunspots, the reversal of the Sun's poloidal field, Hale's law of sunspot polarity, the initial orientation of spot groups and BM-regions, and the dominance of the preceding spot to the following *must* be parts of a large-scale global magnetic process. It will be very important for us, however, to find out of what form and what strength this 'magnetic message' from the solar interior has to be, in order to release the observable phenomena. We are on the other side at least qualitatively sure, that the more than 1000 BM-regions, produced during a solar cycle, after expansion, migration and splitting apart cause the large-scale polar reversal and the reversal of the magnetic configuration of spot groups and BM-regions in the coming cycle. Active Regions are therefore not only products of the 11-year cycle. They are indispensable to keep the solar cycle running.

In this connection I would like also to stress the importance of the so-called 'Giant Cells', discussed first by Bumba (1966). They are fairly regular features with a diameter of about 400000 km, formed by the background field pattern. In analogy to the supergranules these cells are bordered by K emission. New Active Regions seem to form preferably at the junctions of these giant structures. Also the long-lived family configurations of Active Regions, as discussed by Helen Dodson during this symposium need special attention. Both phenomena show that Active Regions are not independent events; their interaction plays an important part in their history. It will also be an urgent and interesting task to confront these results with Babcock's model.

In spite of the fact that an Active Region has a lifetime of a number of solar rotations, its intrinsic active phase lasts only a few days, whereas the violent secondary effects cover a period 3 to 4 times longer. As soon as the full magnetic flux of 10^{21} to 10^{22} Maxwells is being concentrated, the decay sets in. All what is following then is the result of the occurrence of this magnetic flux, its amount, its expansion and its

deformation, which obviously does not seem to be seriously affected by the display of optical phenomena produced by it in the solar atmosphere.

The expansion and the deformation of this concentrated flux will be carried out – strange enough to say – by the same type of convection, if not by the same supergranules, which just before took such an active part in concentrating it. Altogether, the expanding and change of form of a BM-region is certainly not just equivalent to the combined action of the Sun's differential rotation and the random-walk diffusion. There is an increasing evidence that the geometry resp. the magnetic structure of a young Active Region will be affected by the structure of the weak remanent fields, while the form of a well-developed BM-region can be strongly influenced by the collision with other magnetic regions.

As compared to the basic active phase of an Active Region, the decay is a very slow process which is difficult to follow. But just this late period in the evolution of an Active Region with all its problems connected with the nature of the background fields, the role of unipolar and 'ghost' unipolar magnetic regions is of significant importance for understanding the solar cycle as a whole.

The optical and all the other features which accompany the concentration and the

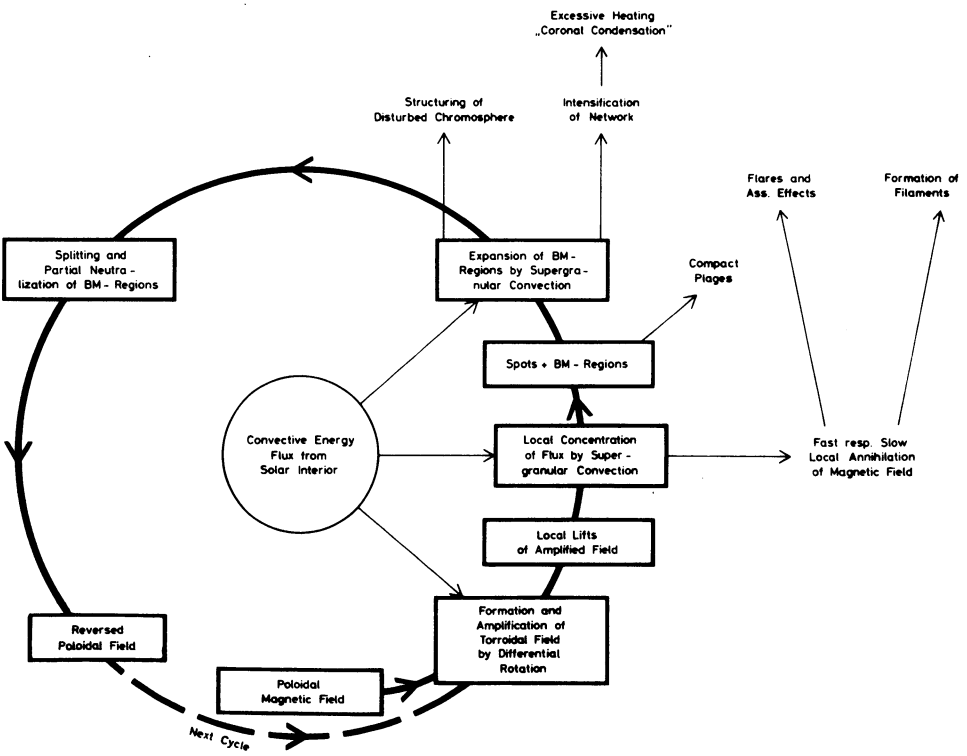

FIG. 1. *The Magnetic Cycle and the Optical Phenomena of Solar Activity.*

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expansion of the magnetic flux, as this becomes clearer every day, are not only influenced or shaped by the magnetic field. They somehow seem to be direct products of it. I am speaking of spots, plages, the structures in the disturbed chromosphere, flares and associated effects, all types of prominences, etc. Flares and prominences, both occurring in regions of horizontal magnetic field (and usually strong gradients of longitudinal field) seem to form as a consequence of a local *annihilation* of magnetic field, very fast in the case of flares, somewhat more slowly for prominences (according to the recent work of Kuperus and Tandberg-Hanssen, 1967). The striking change from the undisturbed to the disturbed structure in the chromosphere, when hit by the expanding field – mainly the formation of thread- and loop-shaped structures – which cover the magnetized region like a curled wig, is not yet quite understood. The fact that these long threads have the same diameter in the photosphere, chromosphere and in the prominences high up in the corona, is probably of some importance.

Altogether, we get the impression, that the formation, the structure and the development of an Active Region is the result of a strange interplay of solar convection, differential rotation, and deeper seated weak magnetic fields. Concentration and expansion of these fields is being done seemingly by the same cellular convection. The more important *observable* phenomena in an Active Region seem to be connected with local concentration as well as annihilation of magnetic fields. The diagram of Figure 1 tries to give a simplified description of this situation.

References

Babcock, H.W. (1963) *Annual Rev. Astronomy, Astrophysics*, **1**, 41.
Bumba, V. (1966) 39. Course Varenna (Plasma Astrophysics). Private Circulation.
Bumba, V., Howard, R. (1965) *Astrophys. J.*, **141**, 2, 1492 and 1502.
D'Azambuja, L. (1953) *L'Astronomie*, **67**, 430.
Dungey, J.W. (1958) *Cosmic Electrodynamics*, Cambridge.
Gold, T., Hoyle, F. (1960) *Mon. Not. R. astr. Soc.*, **120**, 89.
Kuperus, M., Tandberg-Hanssen, E. (1967) *Solar Phys.*, **2**, 39.
Leighton, R.B. (1964) *Astrophys. J.*, **140**, 1547.
Parker, N.E. (1963) *Astrophys. J.* Supplement No. 77, p. 177.
Parker, N.E. (1963) *Astrophys. J.*, **138**, 552.
Severny, A.B. (1964) *Space Sci. Rev.*, **3**, 451.
Sheeley, N.R. (1967) *Solar Phys.*, **1**, 171.
Sweet, P.A. (1956) *IAU Symposium No. 6, Stockholm 1956*, p. 123.
Weiss, N.O. (1966) *Proc. RAS*, **A2093**, 310.