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CONTENTS

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Philippine Geographical Journal, Vol. 34, No. 2
(April-June, 1990)

EDITORIAL

THE KILLER EARTHQUAKE OF 1990: LESSONS AND OPPORTUNITIES

The killer earthquake of July 16, 1990 with a magnitude of 7.7 in the Richter Scale brought immeasurable human sufferings and great destruction of properties but at the same time taught important lessons and opened new opportunities to make life in the future safer and even more prosperous.

As a result of this earthquake, more than 1,600 persons died, about 1,300 have been missing, more than 3,000 have been injured and more than a million have been dislocated socially and economically through loss of homes, jobs, sources of livelihood or properties. Damage to properties as of the end of July 1990 has been put at more than ₱15 million, and is still increasing as additional information trickles in. Such estimate does not include losses in production of damaged facilities and displaced labor force which are bound to be much bigger.

Collapsed buildings, faulted, fragmented or cracked roads, bridges and similar structures as well as massive landslides that buried long stretches of roads and buildings on or near mountain slopes account for the greater part of the damage. The locus of maximum destruction consists of areas near that branch of the Philippine fault which cuts Luzon from Dingalan Bay to the east of Nueva Ecija, through Tarlac, Pangasinan, La Union, Abra and the Ilocos Provinces. A portion of this fault system emerges from Pangasinan to Benguet and other Cordillera provinces. Baguio and its vicinity, which suffered the most, is situated at or near the intersection of two branches of this fault system. In short, although it is not yet possible to predict when an earthquake of any given magnitude in any place will occur, it is possible to determine where major movements during an earthquake are likely to take place.

The Philippine fault system stretches all the way from the northernmost part of Luzon southward through the Cordillera, Central Luzon, Quezon, then through the Bicol Region, Masbate, Leyte, Surigao and Davao. There are other faults cutting the country which can be seen in any tectonic map. These faults are the potential loci of movements during earthquakes. In fact, some of the earthquakes that have hit the country are believed generated by movements along some parts of this fault system.

Damaged buildings and other structures indicate that they were not built to withstand the force of a strong earthquake or they were sited in places which are vulnerable to movements associated with earthquakes. For instance, a five story building that collapsed and killed more than a hundred students was said to have been originally planned for two stories only. Another building which accounted for even more casualties is said to have sustained major damages during an earthquake in 1985. The Kennon Road which is frequently covered by landslides even without earthquakes is a good example of a poorly sited infrastructure.

Certain avoidable factors aggravated losses from the disaster. First, lack of timely information on the extent and location of the damaged communities prevented the sending of rescue and relief teams where they were most needed. It took a couple of days to have a good idea of the damage in Baguio City. It even took about a week or more to know that places in Nueva Vizcaya or even along Kennon Road on the way to Baguio were badly hit. Definitely, it took more than a week to comprehend the extent of devastation wrought by the earthquake. This arose in part due to the disruption of telecommunication and road systems in the affected area and the absence of viable alternatives.

Secondly, there is no government agency that is tasked to monitor such calamity, make instant decisions on what to do, and carry out such decisions. Government was completely unprepared to respond to the calamity. While some foreign countries halfway around the world knew that a major disaster has taken place in the country and were ready to help, it took the government many hours or even days to decide that it should accept external assistance.

Lack of or inadequate rescue and relief organization and preparedness was manifested in actual work. While foreign rescue teams came around with complements of professionals, dogs and hi-tech equipment for locating survivors along with necessary supplies, most of their local counterparts, on the other hand, went to work almost with bare hands, or with rudimentary tools like chisels and hammers to cut through mountains of concrete and steel, and without clear direction and supervision. The only local group which showed a high level of professionalism in rescue operations are the miners of Benguet. They again rendered competent and altruistic services to those victims trapped in collapsed buildings, as they did in past disasters.

Experience gained during and after the earthquake taught us a number of lessons, the most obvious of which are: (1) buildings and other structures were built in areas which are likely loci of earth movements during earthquakes; (2) many of the badly damaged buildings were made of materials not adequate to withstand strong earthquakes; (3) a number of important cities, provinces or even regions which suffered most do not have alternative communication systems apart from limited

telephones, or alternative transportation systems other than some slide-prone roads so that they were completely isolated from the rest of the country, thereby preventing prompt rescue and relief operations; (4) there was no government agency with adequate political clout and resources which monitored disasters, made instant decisions on what to do, and mobilized and directed rescue and relief operations; and (5) there was no agency which informed and trained the citizens on what to do when a major disaster such as the earthquake experienced occurred.

These lessons suggest that to minimize losses from earthquakes and other disasters that are likely to occur in the future, government and society must institute a number of concrete measures, the most obvious being: (1) undertake continuing studies of areas which are likely to be hit by disasters such as strong earthquakes and volcanic eruptions, and develop concepts, methods, plans or procedures on how to mitigate their adverse effects and make such information readily available to all who are interested; (2) institute building rules and regulations which will prescribe the types of structures appropriate in any given area based on knowledge of the geological and related properties of the bedrock; (3) prepare a land use plan which must be strictly adhered to for different geographical or political units which considers as major constraints the geological and other physical attributes; (4) major communities, such as cities, provinces and regions, must be provided with alternative communication and transportation facilities so that they will not be completely isolated from the rest of the country by any calamity; (5) government must create a body staffed by well-trained professionals, provided with adequate resources and political authority to monitor the occurrence of disasters, and mobilize, coordinate and direct rescue and relief operations; and (6) government must organize a body to inform and train the citizens on what they should do in case a major earthquake or any other disaster occurred.

If these measures are instituted and implemented properly, then the killer earthquake shall have opened up new opportunities. We can be sure that avoidable losses shall be reduced to the bare minimum when a major disaster strikes again. Government shall be able to respond with confidence and efficacy during the time of need. Communities, buildings and structures shall be safer than they are now. And there shall be no major community which shall be completely isolated from the rest of the country for a long time by any disaster.

Finally, the massive reconstruction that shall be undertaken shall bring about stronger buildings, roads and bridges — in short a safer and better place to live in. Huge expenditures associated with this recon-

struction are likely to fuel substantial economic growth as numerous jobs become available and the myriads of businesses multiply in support of the construction boom.

Teodoro M. Santos*

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ARTICLES

IMPLICATIONS OF CLIMATIC CHANGE ON OCEANOGRAPHIC CONDITIONS IN THE EAST ASIAN SEAS

Jorge G. de las Alas*

ABSTRACT. It is generally agreed that changes in climatic conditions would invariably result to changes in some of the ocean's physical characteristics as in the case, for instance, of the East Asian seas. It has been found that surface water temperatures in East Asian sea and in Central and Eastern Pacific regions are increasing. Salinity has also been changed by increasing areal mean precipitation and evaporation rates. With global warming of the atmosphere, there will be a tendency to increase the vertical stability of the already stable tropical surface waters. Change in freshwater discharges from continental runoff can generate density currents that can in turn alter near-shore current systems. Limited data has prevented the detection of long-term changes in oceanographic parameters in East Asians seas; hence, there is a need to conduct research on a regional basis to determine the qualitative long-term changes that global warming will bring about in the region.

INTRODUCTION

The ocean is a very important component of the earth's climate system. It provides heat to the atmosphere through the latent heat released by the water vapor it injects into the air. Because of water's relatively large heat capacity, the ocean acts to moderate temperature contrasts over the surface of the earth. Through the major currents, the ocean also helps in transferring heat from the tropics to higher latitudes.

There is general agreement that changes in climate would invariably cause changes in some of the ocean's physical characteristics. Projections of the ocean's responses to climatic perturbations are very difficult to qualify, much more to quantify, due to very limited data bases available. The task of postulating the changes in oceanographic conditions of regional seas due to climatic shifts is even more challenging.

The coupling of the atmosphere and ocean is realized through the various components of the atmosphere-ocean feedback processes shown in Fig. 1. These physical processes include the transfer of momentum

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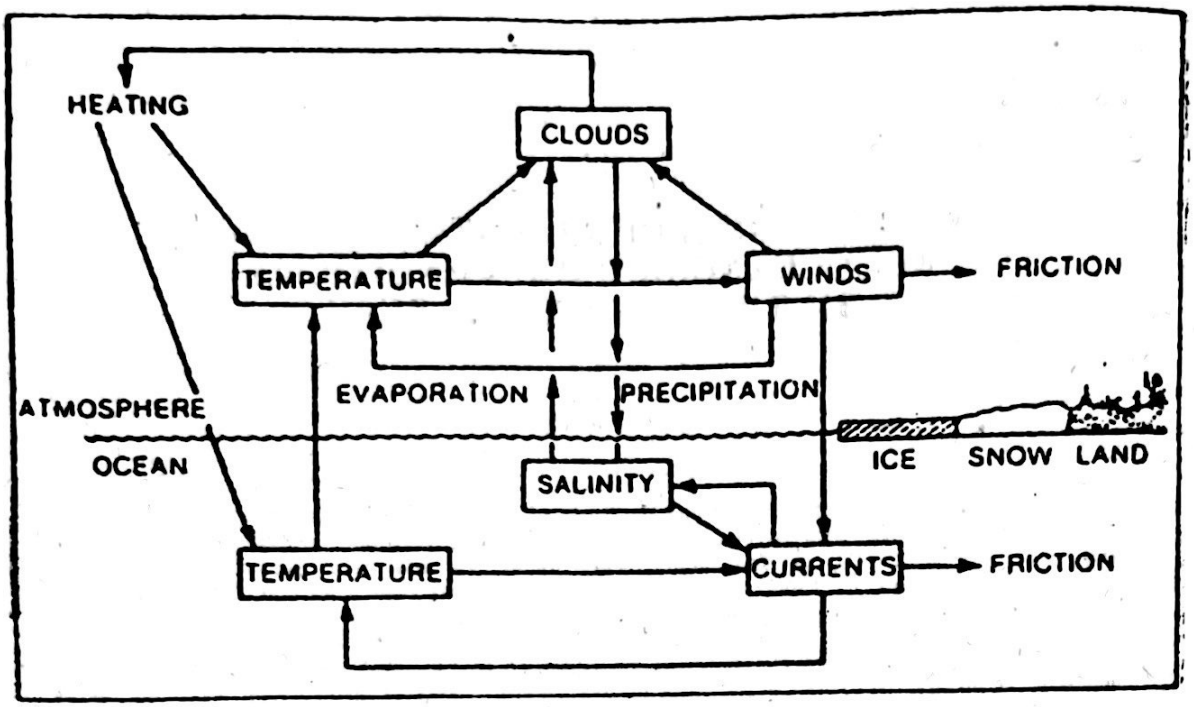

FIG. 1. MAJOR COMPONENTS OF ATMOSPHERE-OCEAN FEEDBACK PROCESSES SOURCE: GATES(1979).

and temperature between the atmosphere and ocean by large-scale motion and small-scale turbulent motion, the selective emission and absorption of radiation, and the evaporation and condensation processes that account for the transfer of latent heat between the two fluids.

A climatic scenario will now be considered where there will be an average 1.5°C increase in atmospheric temperature which might be realized when the carbon dioxide content of the atmosphere will double from its late 19th century value. The increase in atmospheric temperature can now be detected from observations in some Philippine stations. The time series of mean temperatures have been taken for Manila and Aparri stations to show the trend in surface air temperature for a highly urbanized station represented by Manila and for a typical rural setting represented by Aparri. The data show that the long-term mean temperature in Manila increased by about 1°C over a period of approximately 100 years while the temperature of Aparri showed the same increase in about 70 years. The exact increase in temperature may not be accurately established but one thing seems definite: that there is an increase in surface air temperature.

Consistent with this increase in atmospheric temperature is the predicted rise in sea level by approximately 20 cm. The changes in some of the oceanographic properties in East Asian seas will be speculated upon.

EFFECTS ON SELECTED OCEANOGRAPHIC PARAMETERS

Water Temperature

The oceans act as a vast energy reservoir that deposit heat during summer and release energy in winter. They provide the thermal inertia that moderate temperature differences over the earth's surface.

An increase in the temperature of the atmosphere will also warm the ocean surface due to the increase in the long-wave energy reradiated downwards by the atmosphere and the clouds. Because of its large thermal inertia, the surface layer of the ocean will require time in the order of 10 years to complete its response to an imposed thermal perturbation in the atmosphere. The ocean's bottom layer will take a few hundred years to adjust to a new thermal equilibrium level when subjected to the same perturbation.

While there are no available data to verify the long-term changes in sea surface temperature in the East Asian seas region, it may help to present at this point the sea surface temperature time series for the Central Pacific and the Eastern Pacific areas. The data for both areas indicate an increasing trend in the sea surface temperature anomaly.

Surface temperatures in the East Asian seas range from about 20 to 28°C in winter and from about 27 to 29°C in summer. The anticipated changes in sea surface temperature in the region may be considered similar to that expected for the Central and Eastern Pacific regions which is in the order of 1°C.

Salinity

Salinity is one of the major factors that determine ocean water density. Differences in density create currents that help drive the general circulation of the oceans.

Changes in salinity can be brought about by changes in the hydrologic cycle, particularly evaporation and precipitation. Upward adjustment of air temperature and, hence, sea surface temperature would tend to increase the evaporation rate at the ocean surface since it will also tend to increase the water-holding capacity of the air. This enhanced evaporation would tend to increase the salinity of the ocean's surface layer. On the other hand, increasing the amount of water vapor in the atmosphere would tend to increase the amount of precipitation and fresh water runoff which would tend to decrease the surface salinity of the oceans, particularly in the near-shore areas. A global temperature increase would also mean the melting of high latitude ice which would tend to freshen the oceans.

At this point in time, the only available estimates of the change in global precipitation patterns were provided by mathematical models

used to simulate global climate. Tentative results showed increase in the areal mean precipitation and evaporation rates. The geographical distribution of changes in precipitation rates were not consistently reported by various models.

In view of these, it may not be possible at this point to determine, even qualitatively, the change in salinity of the surface waters in the East Asian seas that may result from the warming of the atmosphere.

Vertical Stability

Due to global warming of the atmosphere and the attendant increase in the temperature of the ocean's surface layer, there will be a tendency to increase the vertical stability of the already stable surface waters in the tropics. Vertical stability tends to reduce vertical mixing which has profound effects on the biological productivity of the region.

Horizontal Currents

Horizontal surface currents result from the combined action of surface wind stress and the horizontal distribution of pressure resulting from lateral temperature and salinity distribution while also taking into account the geometry of the individual basin. The change in freshwater discharges from continental runoff can generate density currents that can alter near-shore current systems. Although the current system may be modified by local changes in temperature and salinity distributions, the major potential changes would result from changes in the surface wind patterns. Additionally, there may be changes or shifts in areas of sea surface convergence and divergence which may result in the shifting of downwelling and upwelling areas.

A better quantification of the climatic impact on the current system in East Asian seas may be realized after determining the implications of global warming on the wind and temperature patterns in the East Asian region.

CONCLUSIONS

The anticipated global warming due to increased carbon dioxide content of the atmosphere will definitely affect the ocenographic characteristics in the East Asian seas. Limited observational data prevented the detection of any long-term changes in oceanographic parameters in the area. Oceanic response to global warming is indicated by mathematical models of the general circulation but extension of their results to regional areas must be regarded with caution. Extensive research must be conducted on a regional basis to determine qualitatively the degree of changes that global warming will bring about in the East Asian region.

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CHINA AND THE ECONOMIC FUTURE OF HONG KONG*

Stephen S. Chang**

ABSTRACT. There is a growing economic relationship between China and Hong Kong. The important, burgeoning service sector in Hong Kong, which includes tourism, trade, finance and real estate, has to be supported by wealth generated from foreign and domestic economic activities. China has a great effect on this economic sector's present health and future growth. Manufacturing is reliant upon the cheap labor of the Chinese hinterland. This article examines the proposition that regardless of political considerations concerning 1997, Hong Kong is increasingly economically integrated with China, especially in its southern part.

Hong Kong will be returned to China in 1997 in accordance with the Sino-British agreement. With this accord, there comes a great deal of uncertainty, which was increased by the events at Tiananmen Square and subsequent political tightening in China. Several confidence-building measures and suggestions have been proposed as ways to help with the transition, ranging from extending the "right of abode" in the United Kingdom for "key" people in Hong Kong to attempts to introduce more democracy in Hong Kong prior to its return to China. As the Basic Laws for governing Hong Kong after 1997 are promulgated, the issue of more democracy and, thus, assurances of meaningful autonomy for at least fifty years after 1997 has grown dimmer. Naturally, this affects the basic confidence and economic prosperity of Hong Kong. This article examines the proposition that Hong Kong is becoming increasingly economically integrated with China, and its economic future is very much reliant upon the Chinese hinterland. This would be true even if the return of Hong Kong to China in 1997 were nonexistent.

In the near term, political confidence is all important in affecting the prosperity of Hong Kong. The biggest negative impact is the accelerated emigration of skilled people. The loss of these people creates a "brain drain" for Hong Kong. Many of their skills are already in short supply, so the spectre of emigration merely compounds the problem. These are the people Hong Kong can least afford to lose. Manufacturing in Hong Kong needs to be upgraded both in process and products because of rising labor costs. Hong Kong is also a major financial center in

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Asia. In addition to finance, other service industries, such as import-export trading and business services, need a skilled and educated labor force. The emigration factor is even more critical in light of the above factors.

In addition to emigration, the lack of political confidence may cause capital flight and a reduction in domestic and foreign investments. Local people may hedge their bets and shift some of their assets overseas or investors might consider alternative locations before investing in Hong Kong. In the long-term, political confidence aside, economically Hong Kong is increasingly integrated with and reliant upon China. In the past five years, the service sector has provided most of the new jobs and is growing faster than manufacturing. Much of this can be attributed to its relationship with China (Salem, 1989:52).

Hong Kong's tourism has grown because of its strategic location as a gateway or a convenient added attraction for most tours going into China. Tourist spending has benefited many sectors of the local economy from hotel construction and occupancy to retail stores. After the June 4, 1989 crackdown in China, tourism experienced some decline. Increasingly, it will be linked to and affected by the growth of tourism in China. Hong Kong has plans for a new airport to be in operation after 1997 in anticipation of a future increase in air traffic. There is also hope that a government commitment to a major infrastructure project will improve political confidence in Hong Kong.

China is also Hong Kong's major trading partner. In 1988, 31 percent of Hong Kong's imports came from China as compared to 17 percent in 1978. Hong Kong's domestic exports to China, which were negligible in 1978, constituted 18 percent of the value of its trade, making China its second largest market. In 1979, trade between China and Hong Kong was HK$17 billion (US$2.2 billion), while in 1988 it grew to HK$288 billion (US$36.9 billion) (Andrews, 1989:21).

Re-exports are important to the economy of Hong Kong, and China is the major reason. In 1989, total re-exports of goods into and out of China passing through Hong Kong amounted to US$37.4 billion out of a total of US$44.4 billion, or over 80 percent of the total value of re-exports from Hong Kong. As a point of reference, Hong Kong's total 1989 domestic export was US$28.7 billion (Goldstein, 1990:42-43). An estimated benefit of about 15 percent of the value of re-exports can be derived by the Hong Kong economy through the provision of packaging, insurance and shipping services (*Wall Street Journal*, 1990:A7).

The economic relationship with China is vital for Hong Kong and is destined to increase in importance. However, if China industrializes and develops the infrastructure of its coastal cities, Hong Kong's importance may diminish. Therefore, it is in Hong Kong's best interests

to integrate itself economically with China so that it can be viewed as part of the South China region in terms of economic development and planning.

China has a significant investment in Hong Kong, including such activities as real estate, banking, the stock market and manufacturing. Officially, there are about 500 Chinese companies in Hong Kong, all recognized and approved by the Chinese government. Unofficially, there are between 1,000 and 3,000 Chinese companies in operation. The figure is vague because many are unavowed extensions of parent companies in China, with the primary purpose of evading Chinese financial regulations. An estimate of total Chinese investment in Hong Kong ranges from US$6 billion to US$10 billion. This is larger than investments from the United States, about US$5 billion, or Great Britain, excluding local British trading houses and the Hong Kong Bank (Andrews, 1989: 20-21). In spite of economic retrenchment within mainland China, China International Trust and Investment Co. (CITIC), its official organization for foreign investment, acquired a 30 percent stake in Dragonair, a small Hong Kong airline (Westlake, 1990:62) and announced in December, 1989, that it planned to buy a 10-20 percent stake in Hong Kong Telecommunications Ltd. (Friedland, 1990:34). This indicates China's continued economic and investment interest in Hong Kong.

Hong Kong is an important regional financial center owing to its location within its time zone, liberal tax laws, the relative non-interference attitude of the government (Salem, 1989:53), and a well-developed communications infrastructure. In addition to these advantages, Hong Kong has the prospect of doing business with China. Hong Kong's geographic proximity to such a large market is an undeniable asset. Some investors believe that an investment in Hong Kong today is, in effect, equivalent to a future investment in China. If China maintains its advantages of low taxes and non-interference after 1997 and makes progress in its own economic development, Hong Kong can continue to be a major financial center in Asia.

Part of the real estate market in Hong Kong is reliant upon continued confidence and economic prosperity. Emigration because of pessimism about the future or a drop in foreign business will primarily affect the luxury end of the real estate market which makes up 10 percent of the total. Sales of small-unit apartments will continue to be strong with demand exceeding supply as the people who live in them cannot easily emigrate. The commercial market is very much dependent upon the continued economic activities of Hong Kong in trade, manufacturing and finance. Therefore, the property market, within which Chinese firms have invested heavily at around HK$20 billion (US$2.56 billion), depends on the economic health of Hong Kong which in turn is greatly affected by China both in the medium- and long-term (Salem, 1989:53-54).

The service sectors, trading, finance, regional corporate centers and real estate depend on wealth which has to be created. Wealth in the Hong Kong economy is generated by foreign investments, financial activities, trade, tourism and domestic manufacturing. They add value to the economy while domestic real estate transactions and retail sales to Hong Kong residents merely recycle the local existent money generated by other activities. Finance, trading and corporate centers are enterprises which have to serve primary or secondary economic activities. They either service the domestic manufacturing or the agricultural, mining and manufacturing activities of the Chinese hinterland. The growth of these activities in both areas will fuel the growth of all aspects of the already growing service sector and increase the importance of Hong Kong as a financial center.

Manufacturing in Hong Kong primarily involves the assembly of goods. With increases in labor costs, these products are no longer competitive on the world market. In order to survive, the manufacturing sector has to invest in research and development to upgrade and shift to higher value or more technologically sophiscated products. These efforts have been greatly lacking or non-existent. Instead, manufacturers either ceased operations, invested in other businesses, or shifted parts or all of their operations primarily to Guangdong Province as well as other areas of China to take advantage of the abundant cheap labor. It is estimated that about 30 percent of Hong Kong manufacturing companies have shifted part or all of their production to Guangdong Province (Salem, 1989:52). The income of Hong Kong manufacturers which, in turn, helps to support the service sector, is very much reliant upon the Chinese hinterland.

The recent United States decision concerning China's most-favored nation status, due to expire on June 3, 1990, was of great concern to Hong Kong. Interest groups from Hong Kong lobbied the United States Congress, arguing that it would suffer severely from non-renewal (*Economist*, 1990:25; Goldstein, 1990:43; Rosenthal, 1990:A7). About 70 percent or US$8.5 billion of Chinese exports to the United States in 1989 were re-exports from Hong Kong. Much of these are products from factories established by Hong Kong companies in Guangdong Province and brought back to be finished or packaged in Hong Kong (*Wall Street Journal*, 1990:A7). In 1989, US$1.3 billion worth of United States exports to China passed through Hong Kong (Goldstein, 1990:42). This further points to the importance of the Chinese hinterland in providing support for Hong Kong's manufacturing and trade.

In the long-term, even wages in China will rise. Investment in research and development to upgrade products and the manufacturing process has to occur. Ideally, with a more economically developed and affluent Chinese hinterland as a domestic market, which also provides

a growing pool of scientific talent, financial resources and raw materials, the chances of achieving results are better. Hong Kong by itself is too small. It needs China, assuming that its political climate and the resultant economic policies are suitable.

Hong Kong's service economy is growing in importance. It has to be supported by wealth generated through both internal and external activities. Domestic manufacturing is reliant upon the Chinese hinterland. Financial activities, trade and tourism are affected by China in trying to maintain their current business and future growth. Therefore, regardless of 1997, economically Hong Kong will be increasingly integrated with China, especially the southern part. With this also comes China's political and administrative influences.

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OBSERVATIONS ON THE GEOMAGNETIC FIELD IN THE PHILIPPINES DURING THE MARCH, 1988 TOTAL SOLAR ECLIPSE

Ernesto P. Sonido*

ABSTRACT. The behavior of the earth's geomagnetic field during the March 18, 1988 solar eclipse was observed in Gen. Santos City by the author and the results were compared with those obtained from three other places in the country. More specifically, the behavior of the geomagnetic field was observed during a total and partial eclipse to determine the effects of the event, including the variations before, during and after the eclipse. Observations were made from the 15th to the 19th of March with the assumption that before and after an eclipse there is a uniform electric current in the ionosphere to produce the daily change in the magnetic field and that during an eclipse the electric field and the magnetic field under the eclipsed region are reduced. This phenomenon further indicates a depression of the external magnetopause surrounding the earth over the areas where the total solar eclipse is occurring. Other activities associated with the ionosphere are also affected.

INTRODUCTION

During the total solar eclipse of March 18, 1988, several observations aside from visual/optical means were undertaken, among which was the behavior of the geomagnetic field. This was the first magnetic field observation in the country during a total solar eclpise.

Several teams were assigned to observe the following: the total magnetic field in General Santos City; the horizontal field component in Baguio City and Muntinlupa Observatory; and the vertical field component of the magnetic field in Davao City. The General Santos City team was composed of: Ernesto P. Sonido of the National Institute of Geological Sciences (NIGS), University of the Philippines (UP), and L. Garcia, N. Lance, A. Doniego and R. Valenzuela of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). Observations from the other places were made available to the PAGASA group.

OBJECTIVE

A total solar eclipse is a rare occurrence in any particular place over a period of years, hence we look at this event which lasts for only

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a few minutes as an opportunity to record the phenomenon using new and untried means.

The primary objective was to observe the behavior of the geomagnetic field during a total and partial solar eclipse and to determine if distinct effects could be established and if significant differences characterize the total from the partial solar eclipse, so that a newly discovered technique could be of use other than the traditional optical methods, to analyze some and other effects of variations in the solar radiations on the solid earth, as well as their effects on the atmospheric magnetism of the earth.

The changes in the ozone layer of the atmosphere perhaps may also affect the atmospheric magnetic field and thus magnetic variations may be observed in order to monitor the global state of our environment now and in the future. Such bits of information will increase our knowledge of our environment and can assist us in the planning and wise management of our one and only environment.

RATIONALE FOR THE MAGNETIC FIELD OBSERVATION

The following discussion seeks to justify this project which sought to establish any correlation between the solar eclipse and the magnetic field.

Geomagnetic Field

On the earth's surface, one can observe the main geomagnetic field, which comprises a predominant part that originates from sources in the earth's core and a minor component that originates from magnetic bodies located within the earth's crust. This main field remains consistent in magnitude with time, from thousands to millions of years. Its dipolar shape is distorted from a symmetrical flow to a compressed shape facing towards the sun and to a conical shape whose apex is situated at an increasing distance from the earth while facing away from the sun due to the solar wind. Superimposed on the earth's internal-source field is a small external, transient and variable field arising from large-scale current systems in the ionosphere and magnetosphere that in turn are brought about by the motion of charged particles flowing from the sun into the earth's magnetic field. Short-term time variations of the external part are of course governed by the solar wave(w) and particle (p) radiations. Generally in the past, the w was considered responsible for the regular variations of the geomagnetic field and p as causing solely the irregular variations. However, later studies showed that there is a continuous background solar wind and a p-contribution to the regular daily variation. A highly irregular and oftentimes unpredictable transient field results from solar flares and sunspots known as magnetic disturbances. The sun possesses a magnetic field that affects

the frequency and polarization of the light and radio waves it emits and the effects of which are local changes in the region of sunspots and other solar disturbances. Charged particles from the sun or from space are deflected as they enter the magnetic field of the earth. Collisions of the charged particles dislodge some of the outer electrons from atoms, thus transforming the atom into a positive ion. Such ionized gases (plasmas) are good conductors of electricity. Solar flares and sunspots result in energy releases that raise the temperature and acelerate electrons and protons to near the speed of light, thus causing irregular transient variations in the ionosphere or magnetosphere. The origin and characteristics of the solar flares and sunspots are well-covered in various scientific literature, particularly by Chapman (1951), Tondan (1956), Minsel, D.M. (1959), and many other astronomers and astrophysicists. The variation of the short-term geomagnetic field during a solar eclipse is of smaller magnitude (of the order of 40 gammas), compared to larger variations due to solar wave and particle radiation. This smaller variation was the target of the project.

Solar Eclipse

A solar eclipse occurs when the moon comes between the earth and the sun, in the process cutting off part of the sunlight that otherwise would fall upon the hemisphere of the earth that faces towards the sun. We see the sun due to the part of this sunlight which normally traverses the whole of our atmosphere and reaches the ground. In areas of total solar eclipse, for a few minutes the sun's visibility is wholly covered by the intervening moon, producing a nighttime effect and solar prominences.and allowing the corona to be observed.

The sun sends out light of all wavelengths from ultra-violet to infra-red, of which the ultra-violet (U.V.) ray is ordinarily intercepted in the higher layers of the atmosphere. Part of this intercepted light is able to ionize the air which absorbs it, and when an eclipse cuts off the sun's light, the ions and electrons begin to recombine and the ion and electron content in the ionosphere will decrease. This decrease of the ion and electron content reduces the electric conductivity of various upper layers in the atmosphere which in turn produces the magnetic variations on the earth's surface. Part of the sun's light penetrates into the ground and is irradiated. The sun also sends out neutral corpuscles which also help to ionize the earth's upper atmosphere and whose influx will be interrupted or cut off during a solar eclipse. These corpuscles do not penetrate the ground, but their cutoff can be observed by radio methods and less directly by the magnetic effects.

Chapman (1956) showed that due to the difference between the speed of light and of corpuscles, this results in a difference in the time and cutoff of corpuscles coming from the ionosphere from that of the

ultraviolet light. He defined and distinguished corpuscular eclipse from optical eclipse. The optical eclipse is delayed by a few minutes and seconds and changes in position on earth where the eclipse occurs.

The Effect of a Solar Eclipse on the Earth's Magnetic Field

We decided to make the magnetic field observations as it was possible that with the reduction in the electron and ion content of the atmosphere and corpuscle influx during a solar eclipse, this situation would reduce the conductivity of the upper atmosphere and thus in turn will reduce the intensity of electric currents which produces the transient magnetic variations. The changing magnetic fields of these electric currents above the earth also induce earth currents inside the earth, which will also make a minor contribution to observed magnetic variations. These transient magnetic variations are those that occur and vary with time in the order of a day or less.

We thus predicted that the changing pattern and intensity of electric currents in the upper atmosphere may be obtained by observing continuously or at a few minutes interval, the daily magnetic variations at many fixed observation points. Observed magnetic data will indicate the change in the pattern and total intensity of the electric current in the ionosphere at anytime.

Several days before, during and after the total solar eclipse, the trend of various components of the magnetic field were observed, based on the assumption that before and after the eclipse there is a uniform electric field driving the electric current in the ionosphere to produce the diurnal or daily change in the magnetic field, not subject to any unusual phenomena. Whereas during an eclipse, the electric field is reduced, accompanied by a reduction of magnetic field under the eclipsed region. The change, however, is a mere fraction of the normal main geomagnetic field.

EQUIPMENT USED IN GENERAL SANTOS CITY

The instrument used by the General Santos City team was the U.P.-owned Proton Precession Magnetometer, Model G-856, which is manufactured by EG & G Geometrics of Sunnyvale, California, U.S.A. It measures total magnetic field with a resolution of 0.1 gamma and with observation timed to the nearest second. Digital display of six-digit magnetic field, timed to the nearest second, station number, day of the year and line number could be stored or recorded.

PROCEDURE

For the total magnetic field observation in General Santos City, the Proton Precession Magnetometer was set up in the open ground of the Mindanao Polytechnic Institute, some hundreds of meters away from

any building structure on the 15th of March. To forestall any operator's error, the instrument was set to automatically record the total magnetic field in gammas and timed for every minute from the 15th till 19th of March, 1988. Retrieval of data was done each morning. Based on the World's Total Intensity Map of the earth's magnetic field, the instrument was tuned at 39,000 gammas.

COMPUTATION

Based on observations in General Santos City, the external source (atmospheric) of the erratic magnetic field was established to be highly affected by the sun's activities. During the quiet sun period, the sun's effect was predictable in behavior with time, i.e., steadily increasing in magnitude for the magnetic field from 06:00 h., reaching a maximum around 10:00 h. and decreasing from 11:00 h. until it leveled off around 14:00 h. in Gen. Santos City. This was the trend from the 15th to 17th and on the 19th of March. However, even during quiet sun periods, slight variations caused by micropulsations that have very short wavelengths and that would last for a few seconds to minutes were observed. The profile was smoothened out by applying a five-point weighted running average, although more sophisticated techniques are possible, such as polynomial curve fitting, least squares and digital bandpass filtering. A five-point interval over which the averaging was done was observed for five-minute periods or five-station readings. The weighted average values were plotted in the profiles of observations in General Santos City.

All computations were carried out using the computer system of PAGASA. Computation was undertaken for the five-point running average to smoothen the magnetic profile and adjust magnetometer time to the local time.

The magnetogram for the day of solar eclipse (the 18th of March) was compared with those from the preceding and succeeding days at the fixed station. The magnetogram for the day of solar eclipse is compared with a smooth curve representing the normal daily variation for the same day.

Observation in the Other Stations

To correlate the horizontal (H) and vertical (V) magnetic field results of the other stations of observation with ours, conversion of their results into the total field was also done in PAGASA's computer center by use of vector relationships. To convert the horizontal field to total field, the H is divided by the cosine of the magnetic inclination, and to convert the vertical field into the total field, the vertical field is divided by the sine of the inclination.

The baseline field of the currents observed during the survey is of

the order of 39,000 gammas* for the total magnetic field intensity in General Santos City, and for the horizontal field of the order of 40,000 gammas* in Muntinlupa and 41,000 o in Baguio. Reduction of electric currents in the ionosphere and of magnetic field on stations near the equator was expected to result in distinct magnetic reduction for the horizontal magnetic force and the total field. Considering that the total magnetic intensities in equatorial stations is dominantly of the horizontal magnetic field type, therefore the total magnetic field observation in these stations will be similar to the horizontal magnetic field.

SIGNIFICANT FIELD OBSERVATIONS AND ANALYSIS

For General Santos City

The total magnetic field was observed in Gen. Santos City, one of the two stations where total solar eclipse occurred. On March 18, 1988, the day of the total solar eclipse, observations were recorded from midnight with an initial value of 39,517.5 ɣ with a lot of micropulsations, starting to increase in gradient from 06:00 h. and reaching a maximum intensity at 09:53 h. with a value of 39,605 ɣ. *However, normal trend was disrupted by a steep (negative) decrease in intensity starting from 08:30 h., i.e., decreasing from an intensity of 39,583 ɣ to 39,562.5 ɣ from 09:02 h. to 09:04 h. or a decrease of 32.5 ɣ of 39,595.0 ɣ (value of normal curve at similar time),* increasing in intensity to the maximum at 09:53 h. The period from 08:30 h. to 09:53 h. was the visual observation period of the beginning to the end of the total solar eclipse, whereas the magnetic effects of the eclipse may be considered from 8:30 to 9:05 h. The maximum field intensity plateau ended at 11:10 and descended until 14:20 h. with a value of 39,510 ɣ and from thereon was characterized as very noisy due to magnetic storm, sunspot activity and micropulsations.

For Davao City

Davao City is the other station where the total solar eclipse occurred and where observations of the vertical component magnetic field were recorded. On the day of the total solar eclipse, an initial recording of 39,162 was made at 01:00 h., with no significant change until 06:00 h. from whence a noisy profile increased in intensity that peaked at 09:45 h. with a value of 39,282 ɣ and leveled off until 12:30 h. *However, there was a distinct break in slope from 08:00 to 08:20 h. and from 09:00 to 09:15 h., and the former could roughly be correlated with the start of the depression at 08:30 h. in Gen. Santos City of the same day and the latter with the trough or the total solar eclipse observed visually in both Davao City and Gen. Santos City.* Furthermore, for the vertical field observed in Davao City, there was actually a narrow but steep

* ɣ = gammas

increase as was similarly observed by Kato, Osaka and Sakierol during the 1955 total solar eclipse for a vertical magnetic field. It should be noted that the profile is also very "noisy" as was observed in Gen. Santos City. From 12:30 h., the field dropped off rapidly until 13:20 h. and from thence no significant change was observed.

The change in intensity of the total magnetic field is attenuated during the eclipse by the fact that, while an increase of the vertical component was observed, the total and horizontal field component showed a greater decrease.

For Muntinlupa

Muntinlupa, Rizal was one of the two stations where the horizontal component of the magnetic field was observed during a partial solar eclipse. It was necessary to convert the horizontal component (H) into total magnetic field (T) values for comparability with values taken in Gen. Santos City and Davao City. On the day of the partial solar eclipse, an initial value of 40,472.5 ɣ was recorded at 00:00 h. and with slight saw tooth-shaped changes that persisted up to about 06:00 h. and from thence increased to 40,525 ɣ at about 11:00 h., which was the start of maximum plateau that extended to 12:00 h. *However, observed from 08:50 to 09:40 h. was a 25 ɣ amplitude depression that coincided with the occurrence of the eclipse;* and from 12:00 h. amplitude descended to 40,485 ɣ at 14:00 h. It may be noted that the amplitude of the anomaly was only 12:5 ɣ for areas where partial solar eclipse occurred, whereas in areas where total eclipse occurred, the difference was 32.5 ɣ as in Gen. Santos City.

For Baguio City

Like the field observation in Muntinlupa, a horizontal component magnetometer was used in Baguio City and, for a similar reason, the observed values were converted to total magnetic field values. On the day of the partial solar eclipse — March 18, 1988 — which occurred in Baguio City, a relatively smooth, almost horizontal profile was observed starting from 00:00 h. with a value of 41,147 ɣ and lasting until 06:00 h. But from thereon, a "noisy" profile is visible that increases in value to *41,197.5* ɣ at 11:00 h., maintaining a roughly horizontal noisy curve until 12:55 h. *However, the curve is disrupted by a "depression" located between 09:00 to 10:30 h. with a -6 ɣ amplitude. This depression coincides with the occurrence of the partial solar eclipse over the city.* Beyond 12:55 h., the field decreased rapidly until 16:00 h. and from thereon the change in the field is insignificant.

The Diurnal Magnetic Profile

The observations show that the diurnal magnetic profiles during a normal, quiet magnetic day follow a hump shape within a limited time

confined only during the daytime. The start of the toe of the hump shape is from 05:00 to 07:00 h. but generally from 06:00 h., rising or increasing to a maximum plateau-like or hump shape during the period from 09:00 to 12:00 h. in the low magnetic latitude areas of Gen. Santos City and Davao City and from 09:00 to 13:00 h. in the higher latitude areas of Muntinlupa and Baguio City.

From the magnetic plateau, the magnetic profiles steeply decrease to lower magnitudes, extending generally from two to three hours and from thereon level off more or less. The smooth hump-shape profile is directly related to solar activities during a "quiet" day, hence, any unusual departure from normal behavior observed over a wide area must result from solar disturbances.

As one goes north from Gen. Santos City and Davao City, the magnitude of the total magnitude increased from 39,000 o more or less to 41,000 o as in Baguio City. The amplitudes of depression decrease when comparing sites where total solar eclipse and partial solar eclipse occur and between site locations with latitude differences even when comparing stations during the occurrence of similar solar eclipses. Thus, amplitude at Baguio City was less than that at Muntinlupa as Baguio is farther relative to the latitudes of Davao City and Gen. Santos City.

If the sun's radiation is steadily decreased and then subsequently increased, such as what occurs during the latter half of a total solar eclipse, the total magnetic field profile will drop off momentarily and subsequently recover, which in our observation was for a period of 50 to 55 minutes. Another explanation is that since the magnetic field is a function of the velocity of a charge in the ionosphere, then the magnetic field will increase if there is an acceleration of charge velocity and vice-versa. The moon covering the sun's radiations could decelerate the charge velocity due to an eclipse.

Studies by previous workers have shown that the vertical component may occasionally be affected by local induction effects from crustal conductivity anomalies; whereas the horizontal component H is not affected by these local induction effects. The local induction effects from crustal conductivity anomalies are not affected by the solar eclipse and are small in magnitude as discussed earlier and will affect only the vertical component. In the low-magnetic-latitude region, while there is a decrease in the total and horizontal components, the change in the magnetic inclination is only slight, hence cannot be the main cause of the vertical component increase as observed in Davao City. The local induction effects from crustal conductivity could explain why the vertical component increased during the total solar eclipse in Davao City, and also the vertical component observed in the 1955 total solar eclipse.

SUMMARY

Total solar eclipse occurred over Gen. Santos City and Davao City, whereas partial solar eclipse was observed over Baguio City and Muntinlupa. The magnetic profiles for the total magnetic field and horizontal field show similar trends and unique decrease during the solar eclipse in regions near the magnetic equator. The vertical field increased in a manner similar to the results of the 1955 observations by the Japanese group of Kato, *et al.*; however, due to the higher sensitivity of the recently used magnetometer compared to the previously used obsolete equipment, the observed values cannot be compared. In places where only partial solar eclipse was observed, the magnetic gradient is less than where a total solar eclipse was observed. The project shows that magnetic field observation is another tool, in addition to conventional visual and photographic means, to monitor solar eclipse and to study other solar-to-earth interactions. It is recommended that the total magnetic field or the horizontal component field and measurable magnetic inclination should be measured using proton precession magnetometers. Other phenomena in the atmosphere such as the holes in the ozone layer over the Arctic and Antarctic zones may be monitored by observations of magnetic field by fixed or stationary magnetometers either on the ground surface or perhaps even by mounted equipment in satellites. It must be remembered that such changes in our global environment are now becoming critical due to changes in the atmosphere as well as in the lithosphere and hydrosphere. Perhaps, there is a magnetic link to these changes that may account for such phenomena.

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SOME MORPHOMETRIC PROPERTIES OF THE KOHBARWA BASIN, PALAMAU DISTRICT, BIHAR

Md. Abdur Rob and Mumu De*

ABSTRACT. In the present paper various morphometric properties of the Kohbarwa drainage basin have been examined. Findings of the study reveal that under an almost homogeneous climatic condition and varied morphological situations the basin has been passing through a youthful stage of humid cycle where streams of the lower orders (i.e., first order) dominate the topography of the basin.

INTRODUCTION

The present study incorporates some findings of the morphometric investigations in the Kohbarwa drainage basin of the Chhotanagpur Plateau in Palamau District of Bihar State, India (Fig. 1). This drainage basin covers an area of about 100 sq km. The Kohbarwa Basin is located at the northeastern corner of Ranchi Highlands and the densely forest-clad southern portion of the District of Palamau, Bihar. The basin is bounded by latitudes 23°30′30″N and 30°59′30″N and longitudes 84°08′30″E and 84°15′30″E. The basin is a part of the catchment area of the North Koel Basin. The Kohbarwa Nala is the premier stream of the basin and is a left-bank tributary to the North Koel River.

METHODOLOGY

The study is primarily based on published and derivative data. The work on quantitative geomorphology of the drainage basin of Kohbarwa was done with the help of aerial photographs of 1:40,000 scale and the Survey of India topo-sheets of 1:50,000 scale. A final map of 1:50,000 scale was prepared for morphometric analysis of the basin as developed by Horton (1945) and modified by Strahler (1952). The streams of various orders were counted and measured. The important quantitative geomorphic characteristics of the drainage basin were statistically analyzed and cartographically plotted. Relief properties of the basin have been plotted and analyzed according to Smith's (1950) method of terrain analysis.

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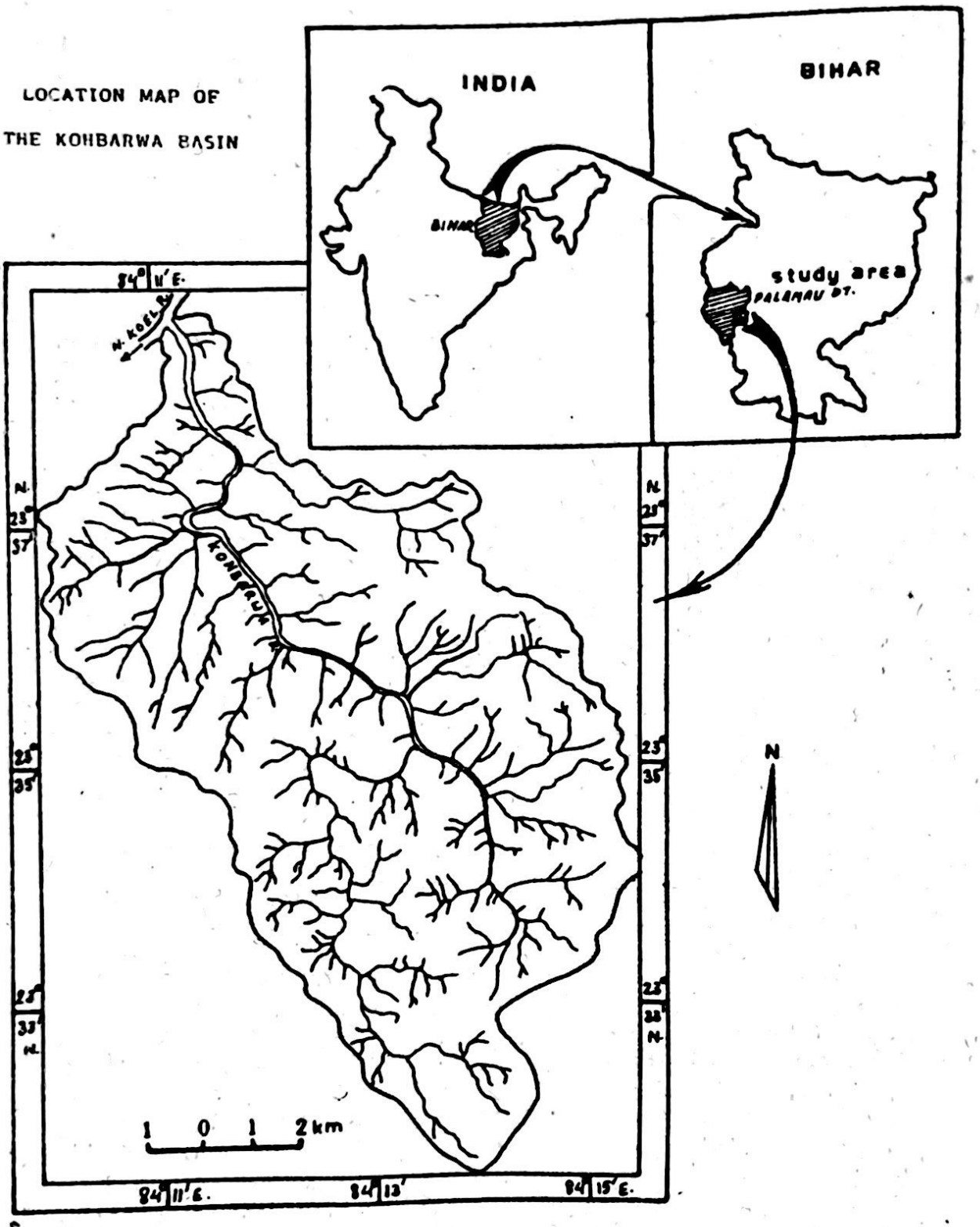


FIG 1

GEOLOGY AND DRAINAGE

The geology of the basin is mainly associated with the rock-types of the Archaean, Vindhyan and Gondwana ages, the last having been cut by dikes of the Deccan trap age. The Chhotanagpur granite-gneiss occupies an immense tract of the basin which lies mainly to the north of Ranchi and Singhbhum districts. It is distinctly intrusive in the iron ore series (Singh, 1958). The Archaean rocks include both the schists of Dharwar age and gneisses and granites as well. The general strike of the structural lines in the Archaeans of the Southern Ranchi Plateau which includes Kohbarwa Basin is normally east-west. The schists, mainly hornblendic and biotitic, are the oldest rocks of the area and occur as parallel and lenticular bands in the gneisses. Calc-silicate rocks and crystalline limestones of Dharwar age are largely developed in certain areas in the basin. New and old alluviums are found in the northwest and southeast and in the central-north and mid-southern portions of the basin, respectively. The structural elements in the area consist of a series of minor folds and cross-folds, with several planer and linear structures associated with these folds (Banerjee, 1964).

The Kohbarwa drainage system is mainly a rain-fed network of streams which receives an average of 1,550 mm annual downpour. The rainy season is from June to September, when the basin gets 85% of the rain water. The peak is reached in August. The drainage of the basin includes both the surface and underground waters. In the winter months, most of the channels of the basin get dried up. The Kohbarwa Nala, the premier stream of the basin, has a total of 231 tributary channels spreading in a total stream length of 380 km over the basin. The drainage patterns found in the basin are radial, parallel, sub-dendritic, dendritic and many other complex forms. The courses of the major channels are mainly meandering.

RELIEF AND TOPOGRAPHIC CHARACTERISTICS

The basin under study represents roughly a trapezium-shaped area with a southeast to northeast alignment. The basin occupies a highly dissected rugged hilly topography with an average elevation of 650 m. The basin attains the highest elevation of about 1,100 m in the south and less than 400 m — the lowest — in the north near the confluence of the river. The general landforms of the basin are marked by wide ranges of relative relief, slope average as well as roughness index. The basin is characterized by the development of a picturesque landscape under multiple cycles of fluvial erosion.

The Kohbarwa drainage basin is divided into two equal halves by the main channel through its mid-line. The Kohbarwa Nala (river), the premier stream of the basin, flows in a serpentine course. It receives the maximum number of tributaries from its lift-side catchment. The

action of fluvial erosion in the basin area is well-expressed in terms of its microlandforms like the residual hills, elongated ridges, scarps as well as the erosional terrains, gullied surfaces and minor ravines. The effects of current fluvial erosion are also well-observed in the dissected valleyside slopes and hillside slopes as well as in the heavily dissected terraces in the lower stretches of the basin.

On the basis of broader morphological evaluation, the whole Kohbarwa Basin can be divided into two topographical divisions: a) the rugged and highly dissected elevated hilly surfaces, and b) the narrow elongated plains and incised valleys.

RESULTS AND DISCUSSION

Studies in Relief Characteristics

The relief or topographic characteristics of the Kohbarwa Basin have been analyzed cartographically. Relief features of the basin portray the total topographic attributes of the land surface. In order to analyze the relief of the Kohbarwa Basin, properties like relative relief, absolute relief, dissection index, roughness index, eohypse picture, etc. have been studied (Figs. 2 to 5). The study of these aspects helps in illustrating the fluvial erosion of an area and its resultant landforms.

Relative relief and absolute relief. Relative relief is the difference between maximum and minimum relief of an area. A higher degree of dissection has been found over the hilly part of the basin where the intensity of river action is maximum and is being supported by considerable variations in relief ranging from 300 m to 400 m. The plain shows 100 m of relative relief line. To understand the relative relief properties, the study of absolute relief is necessary. In the absolute relief map, maximum height is found in the southeast of the basin (1,100 m and above). There is a general decline in relief towards the north.

Dissection index. The dissection index is the ratio between relative relief and absolute or maximum relief. It reveals the nature and amount of dissection in any basin area. For the Kohbarwa Basin, this index varies between 0.2 and 0.4, which means that the terrain is considerably dissected. However, the northern and central areas of the basin remain below the 0.2 dissection index.

Eohypse map. Provided that dissection has not gone too far, it is possible to attempt to reconstruct the contours of the landscape in an earlier stage. The eohypse map of the Kohbarwa Basin shows the general slope of the basin from south to north and in a youth to mature stage of dissection. The extrapolation of contour lines may not be very accurate but they do show the earlier gradient of the area, the reduction of peaks and the amount of dissection.

FIG. 2

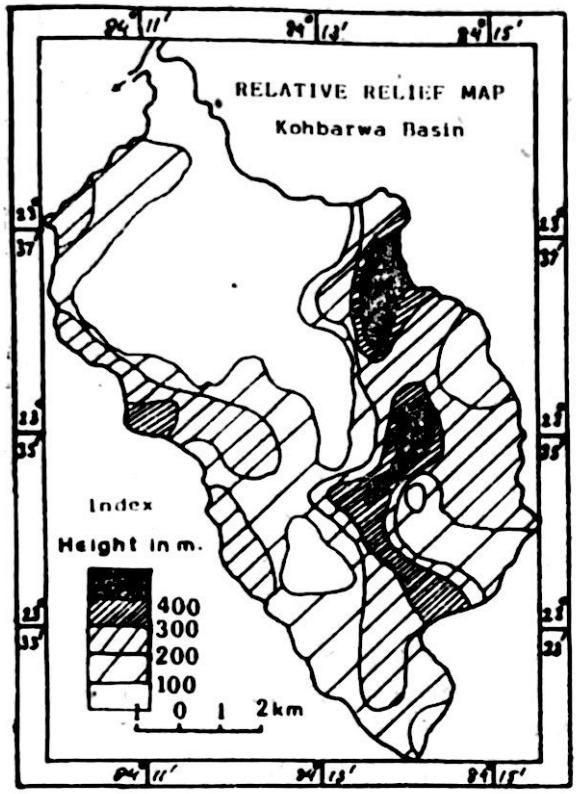
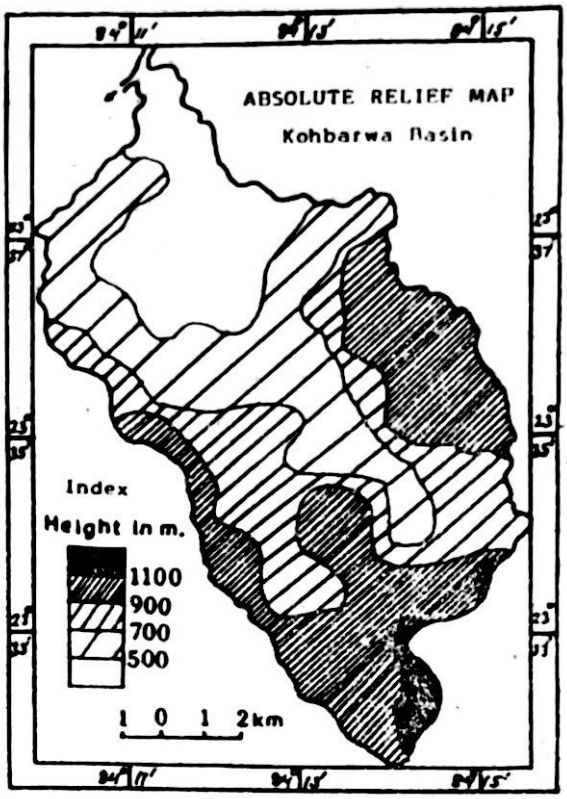


FIG. 3



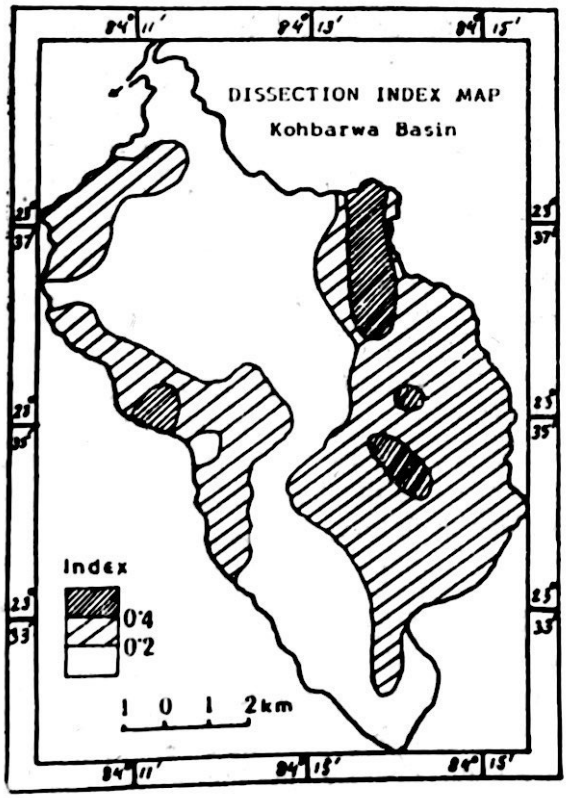


FIG 4.

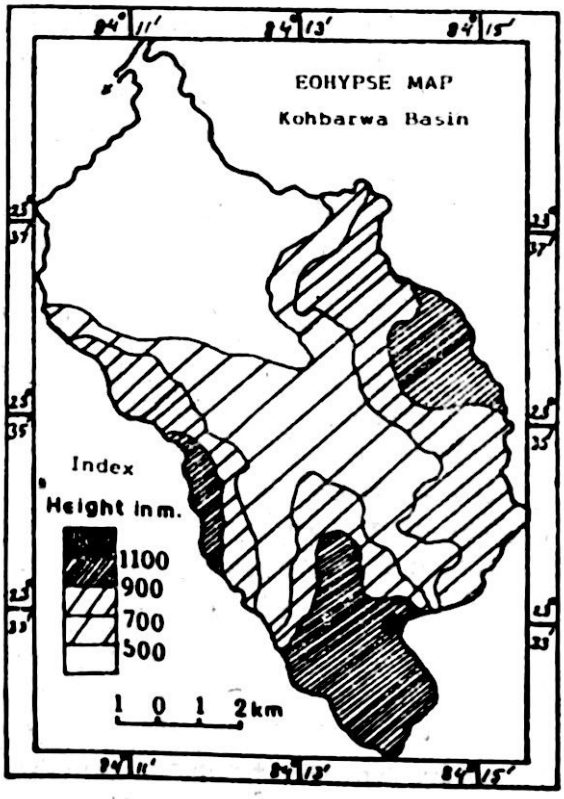


FIG. 5

Roughness index. A higher range of roughness index corresponds with the greater amplitude of relief, drainage frequency and ruggedness number. This index reflects the combined effects of structural control and erosional processes. The roughness index for the Kohbarwa drainage basin ranges between 200 and 800. The value is greater for the eastern, western and southern parts of the basin.

Studies in Drainage Network Relationship

In order to proceed with a rational explanation of the development of the drainage basin, it is necessary to describe its features in numerical (quantitative) terms. The method of classifying the components of stream network into channels of different orders as suggested by Horton (1945) and as modified by Strahler (1964) and Scheidegger (1970) may conveniently be used in a quantitative morphometric analysis of a drainage system. By ordering the stream, the effectiveness of drainage development may be related to stream magnitude and therefore the stream ordering is regarded as an important linear aspect parameter of the drainage basin.

To explain the different drainage parameters and their interrelationships, the various stream orderings of the drainage network are necessary. In the present study of the Kohbarwa drainage basin, Strahler's method of ordering of streams has been considered (Figs. 6 to 9).

Stream orderings. The Kohbarwa Basin covers an area of about 100 sq km and comprises a drainage network of 231 tributary channels of different orders ranging from 1st to 5th. The Kohbarwa Nala, the major stream of the basin, is itself a tributary to the North Koel River and belongs to the 5th order (after Strahler, 1964). The eastern and western parts of the Kohbarwa Basin, along with the southern part, have high elevations and are composed of granitic rock which is resistant to erosion. These parts have numerous streams with lower orderings (1st, 2nd and 3rd) which help in dissecting the terrain moderately.

In certain places, lack of vegetative cover also helps in dissection and erosion. Though the higher-order streams have a much greater volume of water and possess more kinetic energy, the rate of dissection is hindered by lack of slope in the lower reaches of the Kohbarwa Nala. The maximum area of the Kohbarwa Basin is under the first order streams (i.e., fingertip channels).

Drainage density. Drainage density is defined as the length of stream per unit area of the drainage basin. Drainage density within the basin is independent of stream order and it varies inversely with the size of the basin. It also indicates the rock character and vegetation cover. In the basin, the highest drainage density is found in the southern, western and a part of the eastern portion. These areas are

FIG 6

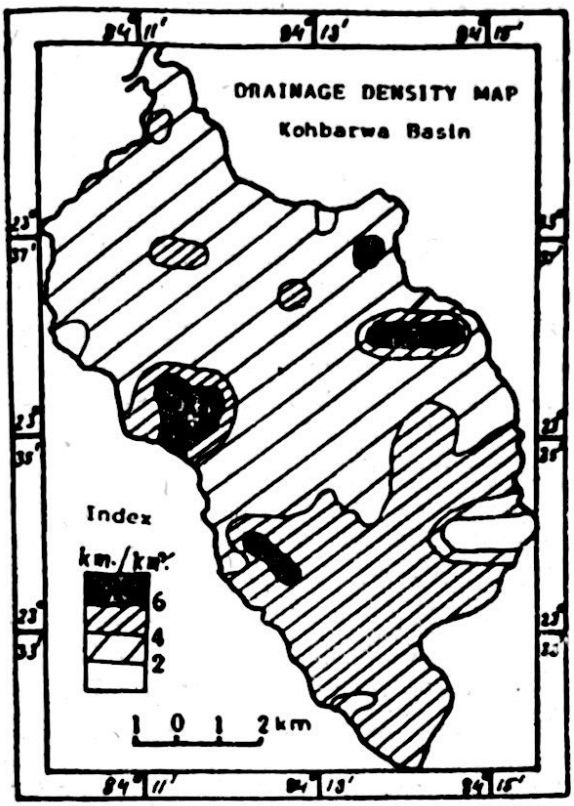
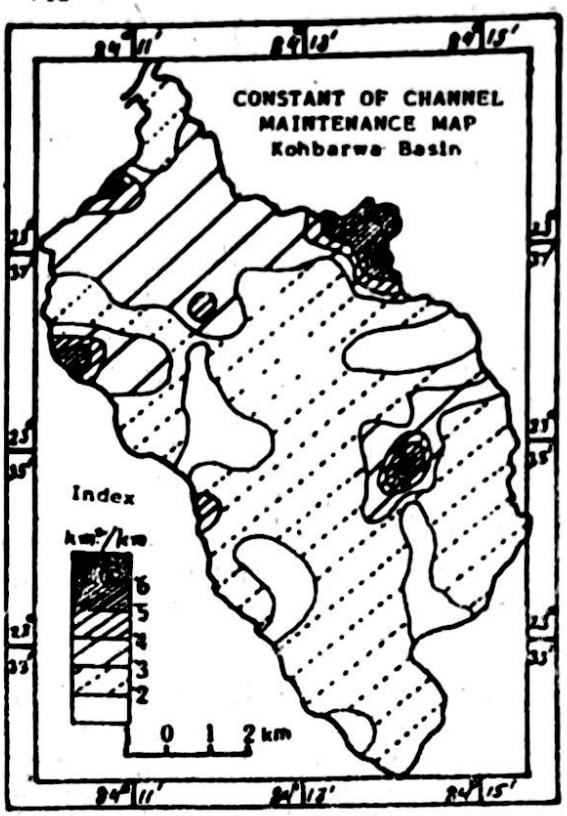


FIG 7



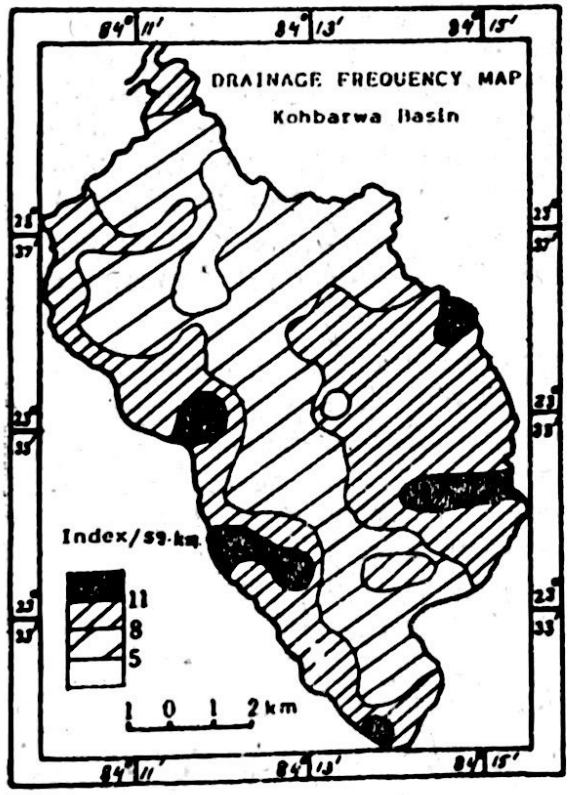


FIG. 8

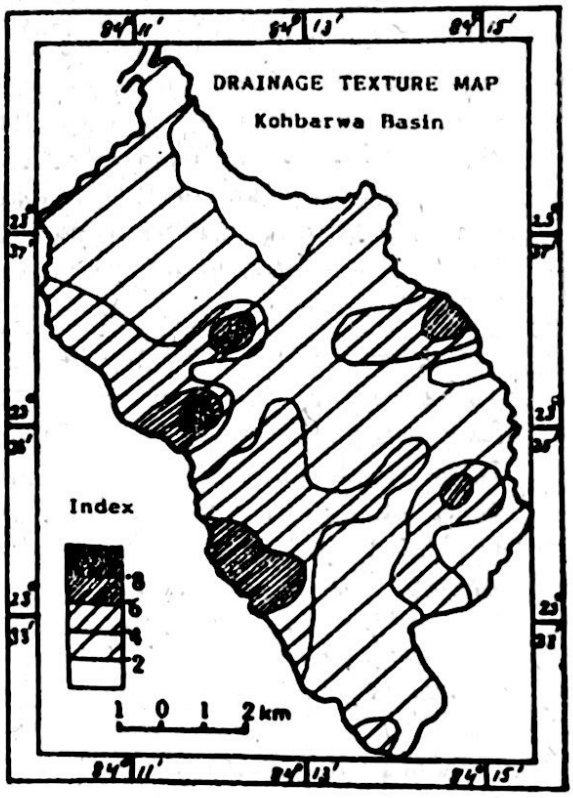


FIG.9

favorable to the development of a drainage network. In the basin, the drainage density ranges from 2 km/sq km to above 6 km/sq km.

Constant of channel maintenance. The constant of channel maintenance is the area which is needed to maintain a stream flow. It is the inverse of the drainage density. The rock character and vegetation of an area can also be indicated by the help of this map (constant). If the rock character is favorable to the development of drainage, a small area is required to maintain the high amount of water. In the Kohbarwa drainage basin, the constant of channel maintenance has been found between below 0.2 km^2/km to 0.6 km^2/km. In this basin, the higher values are found (0.4 km^2/km to 0.6 km^2/km) in patches. The areas with higher drainage density have low constants of channel maintenance.

Drainage frequency. The drainage frequency or stream frequency (F) is the number of stream segments per unit of area. The drainage frequency is useful in studying the texture of the drainage in any basin (Horton, 1945). In the Kohbarwa Basin the stream frequency is found up to 11.00 numbers per sq km of area. Here frequency is higher in the east, west and south. This distribution is also reflected in the distribution of drainage density in the basin. Moderate to lower stream frequencies are (less than 5.02 to 8.0) found along the central and northern mid-basin areas.

Drainage texture. Drainage texture or stream texture is an indicator of spacing of the streams in a basin. The texture of the area is the product of the number of most contour crenulations and the length of the basin perimeter (Smith, 1950). This is related to the drainage density of a basin. The higher the density, the finer the texture. The texture of drainage for the Kohbarwa Basin ranges from 0.2 to 0.8 and is mostly course. Higher values of drainage textures (0.6 and 0.8) are normally localized in patches in the western and eastern fringes of the basin.

A comparison of the relative relief and drainage frequency maps shows that in the extreme southern and southeastern parts drainage frequency is higher (8.0/sq km), although relative relief is only between 100 m to 200 m. The higher drainage frequency is attributed to abundance of surface run-off. In the southeastern part of the Kohbarwa Basin, the relative relief is quite high (greater than 300 m/sq km) whereas the dissection index is between 0.2 and 0.4. Resistant rock types of the area have probably prevented the area from being thoroughly dissected.

CONCLUSION

On the basis of the foregoing morphometric analysis of the Kohbarwa Basin, it can be concluded that under almost homogeneous climatic and heterogeneous morphological conditions the basin exhibits some complex

yet typical morphometric attributes. The study reveals that most of the basin area is passing through a youthful stage of the humid cycle and that fluvial erosion dominates the basin.Streams of lower orders dominate the area. Moreover, the study reveals clearly that the development of the existing morphometric attributes of the basin is linked with both the degradational and aggradational processes. However, the erosional processes of fluvial origin have been predominantly sculpturing the basin. To some extent, these processes are influenced by the subsurface lithology of the basin. The foregoing analysis clearly indicates some relationships among the various attributes of the morphometric aspects of the basin and helps to understand their role in sculpturing the surface of the region. In addition high values of drainage density as well as drainage frequency in the Kohbarwa Basin indicate severe erosion, excessive run-off and hydrological potential.

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