Unstable International Boundaries and FIG Publication NO 76

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1. INTRODUCTION

Stability of boundaries is of utmost importance in peace keeping throughout the world. Delimitation of international boundaries and of internal boundaries of a state, including administrative boundaries and boundaries delimiting land properties and rights of use is very important. The cadastral boundaries are important for ensuring stable legal territorial matters. The law requires fixed unequivocal and unambiguous defining of the boundary lines. Surveyors play a central role in the boundary making process.

The goal of stability of international boundaries has been defined by the International Court of Justice. Practical stability of a land boundary between two states can be achieved by jointly maintaining an agreed demarcated and documented boundary. Lack of stability of boundary delimitations in many cases resulted from unequivocal definitions.

Unstable international boundaries due to unclear or changing reference features -
Selection of unclear and unstable features for international boundary delimitation, either artificial man-made changing features like roads, or improper natural geographic features was common in the colonial time. Mountain crests, water sheds, dynamic physiographic features, such as rivers, lakes and shorelines, were considered as a natural gift for boundary delimitation, saving efforts and resources required for field demarcation. These selections caused many problems regarding unclear interpretation or instability of the boundary line.

Roads and buildings disappear or change through time. Boundary lines along mountain crests cross valleys between mountains. High crests may not coincide with the general watershed lines. Valleys are vaguely defined. Glacier melting exposes different water sheds. Other demarcation problems depend on the dynamic character of chosen natural geographic features. Such are rivers and shorelines that change every second and along the year.

The influence of Global Warming and Population Growth on instability of boundaries -
The origin of many natural geographic feature based problems is an outcome of climate changes and global warming combined with the influence of the population growth all over the world during the last century. Many problems are a result of artificial man-made works.

Global warming and over exploitation of fresh water are a reason for rivers to lose water and change, lakes shrink and in some cases to disappear. It causes glaciers to melt. This causes disputes regarding the boundaries and instability.

River boundaries - The cases of river boundaries are much more diverse and widespread than others. More than one third of the international boundaries throughout the world are river boundaries. Water supply is the most essential natural resource required for human living and therefore a large part of the global population lives along rivers. The need for water leads to development of large artificial water projects on rivers, changing dramatically the natural water flow of the river downstream, and changing its natural balance and behavior. The water flow of rivers is also used for hydroelectric power stations, constructing dams, reservoirs and other works and installations that change the natural behavior of rivers. These phenomena complicate the maintenance of boundaries in rivers, especially due to the trend used in many boundary agreements that the boundary follows continuous gradual natural changes in the river and does not follow artificial changes in the river.

The extent of global warming and man-made influence on the natural river flow and behavior all over the world leads to severe problems regarding boundaries in rivers everywhere. This raises questions regarding changes in traditional trends and doctrines (adopted since the Roman times),considering preference of stabilizing the boundary delimitation in the river, fixing it by coordinates, and regulating accessibility, and rights of use and exploitation, in a separate agreement.

Boundaries in lakes – As a result of global warming and of over exploitation of water for the requirement of growing populations, lakes lose water and partially dry up. Such one is Lake Chad due to agricultural irrigation. Such one is the Dead Sea because of excessive evaporation through industrial salt pans. In the case of Lake Chad part of the coastal states lost access to its water. In the case of the shrinking Dead Sea Israel and Jordan fixed the coordinates of the boundary line.

Boundaries on glaciers – Glaciers melt due to global warming, including the Andes, Himalaya and the Alps, where boundaries follow icy mountain crests. The water shed along the exposed rocky crests differs from the pre melting icy water shed. Since the boundary line used to be delimited along the old icy crests the neighboring parties have to define where should be located the new boundary. Italy and its northern neighbors – Austria and Switzerland – have adopted an approach called the moving border, agreeing that the boundary line follows the new location of the water shed.

Boundaries on dynamic land moving due to tectonic activities - Tectonic plates all over the world keep moving carrying on also boundary markers. For example, an Iraq-Kuwait Boundary survey monitored movement of tens of centimeters after 20 years. This raises the challenge to maintain on the long run stability of coordinates of international boundary markers, arguing that local reference systems may not be adequate for maintaining the stability of international boundaries. It raises a possible consideration to connect boundary reference networks to regional densification of ITRF.

It is worth mentioning that natural phenomena that influence the stability of international boundaries are sometimes interrelated. Movement of tectonic plates along the course of a river may directly influence its course, or indirectly because of collapses of its walls that block its flow, enforcing it to find or create a bypass. The melting of glaciers, that influences the boundary line along crests, may also have an influence on the boundary line in a lake, by causing a rise of the water level and horizontal changes in the coastlines of the lake. In the case of a river and a lake that both serve for boundary delimitation, if the lake partially dries, the river has to find or create a new channel through the dried area in order to get to the lake. This new channel is usually not identical with the old boundary line in the lake.

These subjects are discussed in FIG Publication on International Boundaries on Unstable Ground

https://fig.net/resources/publications/figpub/pub76/figpub76.asp

2. UNCLEAR BOUNDARY DELIMITATION AS A REASON FOR DISPUTES

Most of the international boundaries have their roots in colonial times: they were delimited during the 19th century and the beginning of the 20th century. The delimitation of these boundary lines created many problems, such as ignoring the interests of the local population, cutting off tribes and their living areas by straight delimiting lines, or by other lines that do not take into account the local geographical, historical, ethnical, cultural, and other considerations. In addition to these problems the delimited lines suffered from many defects.

In order to save resources for boundary demarcation, the trend and the first choice was to describe the boundaries by referring to prominent natural features.

Selection of unclear and unstable features for international boundary delimitation, either artificial man-made changing features such as roads, or improper natural geographic features was common in colonial times. Mountain crests, water sheds, and dynamic physiographic features, such as rivers, lakes, and shorelines, were considered as natural geographic features for boundary delimitation, saving efforts and resources required for field demarcation. These selections, however, caused many problems regarding unclear interpretation or the instability of the boundary line.

For example, roads and buildings disappear or change over time. Boundary lines along mountain crests cross valleys between mountains. High crests may not coincide with the general watershed lines. Valleys are vaguely defined. Glacier melting exposes different water sheds. Other demarcation problems depend on the dynamic character of the chosen natural geographic features, such as rivers and shorelines that often change continuously throughout the year.

In addition to these examples of selecting improper features for the delimitation, technical problems have often affected the clarity of the delimitation. In the worst cases the delimitation depended only on a verbal description. The delimitation in these cases was very vague, and each party had various interpretations. Names of places, including villages, mountains, wadies and other places changed over time, and sometimes the same names were used for different places, often kilometers away. Geographical terms were often misused. When a center of a valley is used for describing the boundary line and the width of the undefined valley is vaguely defined between ten and twenty kilometers the interpretation of the center of the valley may raise a dispute of kilometers regarding the boundary line. In cases in which maps were used, their scale was usually too small, in some cases 1:250,000 or 1:500,000 which means that one mm means 250 or 500 meters in the field. In addition, the quality of the maps was poor. The accuracy of the placement of features on the map could be worse than 1 mm, and often many features did not appear on the maps. Thus, the accuracy of delimiting the boundary line on a map could involve a discrepancy of hundreds of meters and even kilometers. Such vague delimitations, either verbal descriptions or use of poor maps, may lead to disputed interpretations regarding the magnitude of hundreds of meters and even kilometers.

3. INSTABILITY OF BOUNDARIES RESULTING FROM GLOBAL WARMING AND POPULATION GROWTH

Many natural geographic feature-based problems stem from climate changes and global warming, combined with the influence of the worldwide population growth during the last century. Many

problems result from artificial man-made works. The relevant problems due to global warming refer to boundary lines delimited with reference to water bodies, for example, river boundaries, boundaries in lakes and marshes, boundaries along shorelines, and boundaries on glaciers

Global warming and over-exploitation of fresh water are the main reasons why rivers lose water and change and lakes shrink and sometimes disappear. This causes disputes regarding the boundaries and causes instability. The world population has multiplied five times during the last century and is continuing to grow. The water consumption of the increasing population, either directly or the use of water for food production, energy, industry, and economic growth has severe implications regarding international boundaries in these water bodies. It involves construction of large-scale engineering projects, as well as changing the natural rivers and lakes. Lack of water, food, and available energy as well as ensuring economic growth are serious challenges to the United Nations Sustainable Development Goals. Thus, often artificial intervention is essential and urgently needed.

The impact of the drying process on rivers due to global warming, combined with the influence of the worldwide population growth along with artificial man-made works along rivers, has dramatically changed the natural water flow of rivers downstream, and has changed their natural balance and behavior. These phenomena complicate the maintenance of boundaries in rivers, especially due to the trend used in many boundary agreements that the boundary follows continuous gradual natural changes in the river (accretion) and does not follow artificial changes in the river. The extent of man-made influence on river flow all throughout the world has led to severe problems regarding boundaries in rivers everywhere. This reflects the severe disadvantages of choosing natural geographic features for international boundary delimitations, which were used in the past, and especially for the common trend of using rivers as international boundaries.

Global warming causes glaciers to melt so that under a glacier base the ground is gradually exposed. Since the boundary line on glaciers used to be delimited along the crests of the glaciers, the result of the melting process of the icy natural crests is that the newly exposed bare rocky mountain crests are located in different locations than are the icy crests. Since the boundary line used to be delimited along the old icy crests the neighboring parties have to define where the new boundary should be located.

4. THE SCOPE OF FIG PUBLICATION NO 76 REGARDING THESE ISSUES

Chapters 1, 2 and 3, deal with boundaries in rivers and lakes. Chapter 1 elaborates on methodological aspects regarding river boundaries. Chapter 2 elaborates on the practical case of the international boundary between Israel and Jordan, in its river section that follows the Jordan and Yarmuk Rivers. Chapter 3 deals with boundaries in lakes, showing examples of the shrinking of the Aral Sea and Lake Chad; it elaborates on the example of the changes in the Dead Sea level and shores due to global warming and the detrimental influence of man.

Chapter 4 deals with the boundaries of Italy on the glaciers of the Alps. It analyzes the continuous gradual process of ice melting over the last century as a result of global warming.

The original agreed delimitation of the international boundaries along the crests of the mountains used to be on icy crests. However, the melting of the ice exposed the rocky crests. The article analyzes the process of negotiations between the concerned parties and introduces the chosen solution termed the moving border.

Chapters 5 and 6 deal with the uncertainty of the delimitation and demarcation of international boundaries in the long run, due to dynamic plate movement. Chapter 5 examines the geodetic and geophysical issues that earth dynamics may impose on the reliable enduring definition of boundaries; one becomes aware that no place on the surface of the Earth can be truly considered to be fixed in place due to pervasive, continual tectonic motion. The practical case of the Iraq-Kuwait Boundary is discussed. Chapter 6 reviews surveying standards and datums used to support boundary positioning. Poor boundary delimitations may contribute to instability of the boundary and to boundary conflicts. It refers to the problem of maintaining the permanent stability of boundary monuments and coordinates, arguing that local reference systems may not be adequate for maintaining the stability of boundaries; it suggests that boundaries should be connected to a regional densification of ITRF.

FIG Publication NO 76 has been prepared under the framework of FIG Commission 1, WG 1.3 on International Boundary Settlement and Demarcation.

5. RIVER BOUNDARIES

The cases of river boundaries are diverse and widespread. More than one third of the international boundaries throughout the world are river boundaries. The impact of the drying process of rivers due to global warming is combined with the influence of the population growth all over the world and with artificial man-made works along rivers. Water supply is the most essential natural resource required for human living and therefore a large part of the global population lives along rivers. The need for water leads to development of large artificial water projects on rivers, sometimes building big dams and reservoirs, changing dramatically the natural water flow of the river downstream, and changing its natural balance and behavior.

Rivers around the world are diverse regarding their size, their flow, their behavior during various seasons, the use of their water and additional parameters. The basic distinction regarding this subject refers to whether the rivers are navigable or non-navigable.

The main problems regarding international boundaries in rivers arise in cases where the boundary line has to be changed owing to a change in a course of a river. This often causes problems in preserving the stability and initiates disputes between states, either because of the loss of territory of one of the states or because one of the states loses accessibility to the river, losing rights of using the river's water. Such complications may be more severe in navigable rivers. States may overcome such problems by signing supplementary agreements, to ensure their rights to use the river waters in such cases. In extreme cases states may agree on taking drastic measures, such as forcing the stream into a steady water course.

Legal principles regarding land boundaries in rivers in cases of changes in the water course have been established and implemented since the time of the Romans. These principles distinguish between two types of changes in the water course of a river: one is a natural, slow and gradual change during the accretion/alluvion process. It cannot be perceived when it occurs, when the water of a river carries away soil from one bank of the river to its other side (usually under different ownership). In the case of an international river boundary, the river often carries away soil, transferring a piece of land from one state to another. According to the accretion principle, in such cases the boundary line follows the changes in the course of the river, and the course of the boundary line is consequently changed to the new location of the river course.

The other case refers to a sudden and steady change in the water's course (avulsion), which can be perceived when it occurs, either as a result of natural reasons or as a result of man-made activities. According to the principle of avulsion, such a change does not justify a change in the boundary line. This case should be considered as if a new river has been formed elsewhere. The boundary line remains in the former abandoned water course even if it is dry. In this case there is a break off between the course of the river and the course of the boundary, and one of the states loses its access to the river at this location.

In order to avoid situations of unstable boundaries that are predicted to cause future disputes, some countries have tried to fix the river boundary between them, with reference to the position of the course of the river on a jointly agreed date. In order to overcome the dynamic nature of the river, they have tried to physically force the river's flow into a rigid concrete canal. Usually this did not solve the problem because new problems arose. In other cases, countries agreed to fix the boundary line in coordinates. This option is much easier to implement today than in the past, since the use of satellite surveying, like GPS, is much more common. Even the International Court of Justice has adopted this method in its decision concerning the dispute between Benin and Nijer.

There is no obligatory international convention regarding river boundaries similar to the UN Convention on the Law of the Sea (UNCLOS 1982). As a result, states rely on decisions of ICJ and international tribunals, on customary practice of agreements between countries, and on studies of scholars. The doctrine that a boundary line in a changing river follows the changes in the case of accretion, when the changes are natural, gradual and not perceivable when they are formed and does not follow the changes when they are sudden or when they are a result of man-made activities – has not been accepted as an obligatory principle in international law. This doctrine has been adopted in many cases and fulfils many criteria that check the qualification of principles to be considered as international law. However, ICJ did not decide on it unequivocally, and there are countries that do not adopt these principles in their agreements in order to avoid local complications.

A change in a course of a boundary line transfers land from one country to another. This is harmful to the population of the losing side, to the stability of the boundary and to the relations between the two countries. On the other hand, breaking off the connection between

the course of the river and the course of the boundary prevents the accessibility of the residents of one of the countries to the river, thus affecting their use of this essential resource. Even if it is concluded that for the sake of stability and legal clarity it is recommended that countries should avoid delimitation of boundary lines in rivers, and with reference to geographic landscape features that are not precise and unequivocal, one cannot ignore the fact that river boundaries make up one third of the international boundaries throughout the world. A relevant global phenomenon that influences the situation of rivers is the dramatic population growth during the last century, which has sharply increased the use of rivers and their pollution. Other influential global developments include climate changes that damage water sources, increasing irregularity of river flows, especially in areas that are on desert edges, characterized by seasonal floods. Lack of water caused many countries, sometimes under the framework of multinational projects, to regulate the flow of water in rivers, to stabilize it by constructing dams and artificial water reservoirs, to stabilize the river banks or to canalize the river bed. Projects of water collection and water use, including pumping out water before it gets to the river, or sometimes along the course of the river, contribute to the drying out of rivers, and are considered artificial human intervention in the natural flow of rivers, so that most of the boundary rivers cannot be considered as preserving their natural behavior. These artificial changes, rule out the rationale of referring to the natural behavior of the river that stood as the basis of the principle of accretion. If the transfer of soil by the river is influenced by man-made activities, it is not right to grant a country the right to unilaterally influence the flow and course of the river, and as a result to change the boundary line in favor of that country, adding lands to the country's territory on the account of another country.

In light of this situation, it is often right to fix the boundary line in the river between two countries, according to the course of the river on an agreed reference date, and to deal with separate accomplishing agreements regulating other issues connected to the river. Such issues may include accessibility and rights of use of the river waters by the two countries, covering the issue of possible local changes in the river course in reference with the boundary line.

In Chapter 1 of FIG Publication NO 76 Haim Srebro elaborates on issues regarding international boundary delimitation and maintenance in rivers in light of legal principles, court and arbitration decisions, bilateral agreements, and customs regarding delimitation of international river boundaries, and regarding the attitude to the delimitation in cases of changes in the river's course.

In Chapter 2 of the FIG Publication NO 76 Srebro elaborates on the practical case of the Israel-Jordan international boundary line in the Jordan and Yarmuk rivers. He reviews the boundary delimitation and boundary maintenance in the rivers with reference to the traditional approach, as well as practical implementation challenges facing dramatic influence of artificial intervention and natural drying processes in the two rivers.

6. BOUNDARIES IN LAKES

Delimiting an International Boundary in a Lake

Srebro elaborates on boundaries in lakes in chapter 3 of FIG Publication NO 76.

Most of the international boundary lines in lakes are delimited along the median line (the center line) of lakes. Others, especially in cases of narrow lakes that are located along navigable rivers, are delimited along the main channels of navigation in the lakes. In the past, boundaries were delimited sometimes in lakes along arbitrary straight lines such as parallels or agreed azimuth lines. Sometimes the boundary lines consist of straight line sections. This is usually the case when the delimitation experts agree to simplify the curve lines, similar to the median lines, by incorporating straight line sections, thus compensating for the discrepancies between the lines.

The median line defines a line, every point of which is equidistant from the opposite shore lines. One of the main problems in delimiting boundary lines that depend on the shorelines is that the shorelines are not stable. They move due to changes in the water levels between high tide and low tide and between seasons, as a result of drought, heavy rains, or snow melting, or even as a result of erosion of the banks of the river.

The influence of natural and artificial changes on boundaries in lakes

Severe problems regarding the delimitation of boundaries in lakes result from the conflict between the basic requirement for boundaries to be exact and fixed, and to provide stability while considering that lakes are water bodies that do not maintain a permanent size. Owing to severe natural and man-made changes during the last half century, this situation is rapidly changing. The most prominent changes are due to climate change and global warming.

A research study at JPL, which checked the surface night temperature of 167 large inland water bodies all over the world during the years 1985-2010, monitored warming of over 1 degree up to 2.5 degrees for the entire period.

An extreme case showing the influence of global warming on the shrinking and drying process of lakes, which was involved in international boundary delimitation, can be exemplified by Lake Aral (Aral Sea), the fourth biggest lake in the world in the 1960s. The international boundary between Kazakhstan and Uzbekistan was delimited in the Aral Sea. Most of the section of the international boundary line that previously used to pass through the Aral Sea currently follows practically dry land, as is shown in the following illustration, showing the drying process of the lake between the years 1989 and 2014.

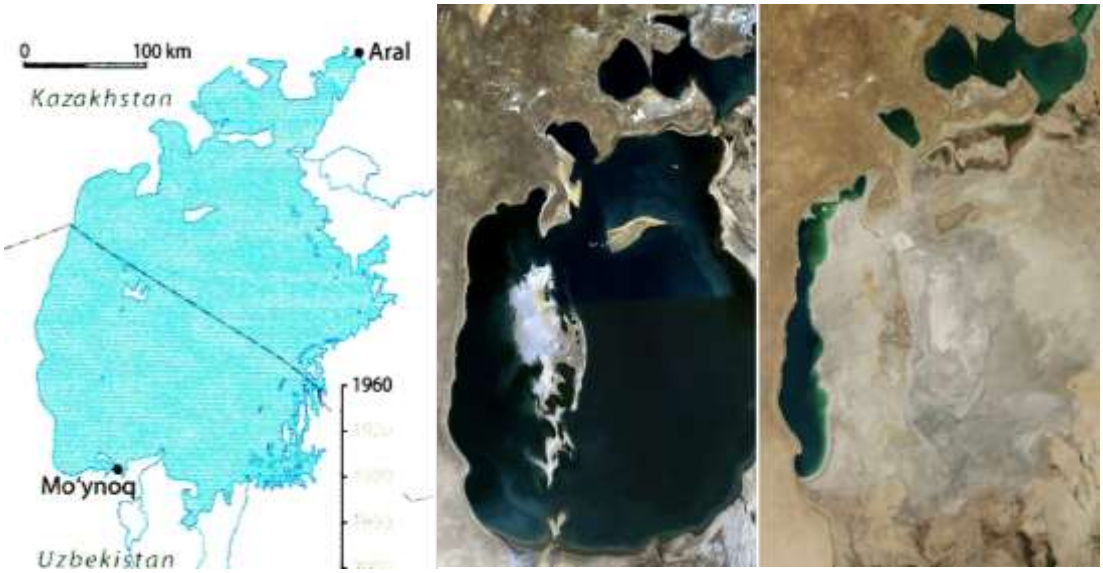

Figure 1: The shrinking process of the Aral Sea – On the left a chart of the size of the lake in 1960 (from Wikimedia –Author: NordNordWest using Nasa images, US NIMA data, www.unimaps.com). In the middle: A mosaic of LANDSAT images, July-September 1989. On the right: An image of NASA MODIS on TERRA satellite, August 19, 2014.

Another extreme case showing the influence of global warming and over-utilization of water (for agriculture) can be seen in Lake Chad. The international boundaries of four countries traverse the lake: Chad, Niger, Nigeria, and Cameroon. In the past, this lake was considered as the sixth largest lake in the world (similar in size to Lake Erie) and the largest one in Africa. According to a research study in Madison-Wisconsin University (Coe M.T. & Foley J.A., 2001), using NASA's Earth Observing System Program images, the lake shrank to 1/20th of its original size within 35 years!

Regarding the warming phenomenon, the annual rainfall in the area dropped drastically since the early 1960s. Regarding the over-utilization of water, the quantity of water that was diverted from the lake for irrigation from 1984 to 1993 was three times larger than the lake water used during the preceding 25 years.

The rapid global population growth and the growth of water consumption, either directly or for agriculture, food production, and for industry, has contributed to large-scale projects regarding water all over the world, especially in arid and semi-arid areas. In addition to the natural warming influence, the global water balance suffered a reduction of water sources as a result of man-made artificial changes in lakes and rivers. These activities include the following: 1) Construction of big dams, such as the Aswan Dam and dams on the Euphrates River, which created very large artificial lake reservoirs, enabling regulated and controlled use of water, and avoided the traditional dependence on seasonal and annual climate changes. Lakes and large lake reservoirs may be used to divert part of the water through canals and other water carriers for external use, in a way that may significantly reduce the original water volume. 2) Construction of dams for hydro-electric projects sometimes includes digging and

constructing large reservoirs that change the natural original river and lake, which influences the international boundary line. 3) The global population growth and the increased water consumption decrease the water sources and the water volume of lakes, shrinking their size causing their disappearance.

In cases where international boundary lines traverse a common lake, the contraction of a lake area directly affects the riparian areas of the lake, since the shrinking is not symmetrical between the areas, but instead, it depends on of the structure of the lake bed and its bathymetric characteristics. For example, the shallow areas are dried first and consequently, the shorelines change appreciably.

Conclusions

Global changes, including global warming and population growth during the second half of the 20th century and the beginning of the 21st century, have contributed to the drying of lakes, especially in dry and arid areas. This phenomenon has implications regarding the historical balance between riparian states that share rivers and lakes, regarding the delimitation of boundaries between them, as well as regarding the right to use the water bodies.

A process of asymmetric drying of the surface of a shared lake continuously changes the median line of the lake and the proportion of an agreed partition of the lake between the respective states. If the relevant parties prefer to fix the boundary lines in order to preserve their stability, it may influence the agreed balance regarding the rights to use the water, and in extreme cases, it may influence the accessibility to the lake. On the other hand, if the respective states prefer to preserve equity or an agreed upon relativeness regarding their rights of use and exploitation of the water of the lake, they must change the boundary line, and thus, affect the stability and functionality of the area, which is the main aim of international boundary delimitation. An alternative option dealing with a dynamic and evolving situation is to fix the international boundary delimitation and to agree on all the rights of use, the practical arrangements, and the preservation of equity separately, in a different agreement, or as a supplemental part of the boundary agreement.

7. BOUNDARIES ON GLACIERS

Andrea Cantile elaborates on boundaries in lakes in chapter 4 of FIG Publication NO 76.

The most significant changes in recent years along the Italian borders have been a direct consequence of the melting of glaciers on the Alpine peaks, as a result of which the boundary line defined by the watershed was changed with the outcrop of the underlying rocky surface.

During the periodic reconnaissance of the boundary pillars along the Italian-Austrian and Italian-Swiss borders, several phenomena of morphological transformation of some alpine glaciers have been observed resulting from the climatic variations.

In these areas, where the ridge lines of the glaciers also identified the boundary lines, a discrepancy was therefore caused by the non-coincidence between these two elements. This phenomenon could be ignored, as normally occurs in the valleys, following the planimetric variation of the borders coinciding with the natural water courses, or could be subjected to adjustment, as shown in the figures 2 and 3.

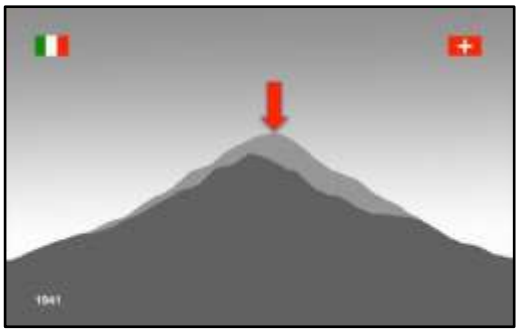

Figure 2:
The red arrow indicates the position of the boundary line on the glacier ridge.

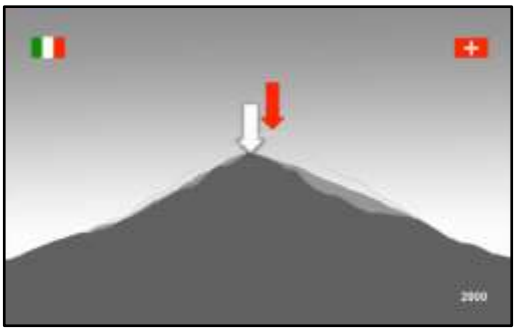

Figure 3:
The white arrow indicates the position of the boundary line after the melting

These phenomena, observed for about a decade, between the seventies and eighties of the last century, led to the study of a proposal, previously discussed informally with the technicians of the Austrian and Swiss Commissions, on the basis of which, it was agreed on the need to «introduce, within the framework of the existing agreements [...] relating to the common border, a provision with which it is established that the border line coinciding with the glacier ridge can follow the gradual and natural changes of the line ridge, and therefore be considered moving».

Apart from the subtle differences present in the texts of the two agreements between Italy and Austria and Switzerland, the novelty introduced only tends to highlight and accept the principle according to which «the boundary route can follow the gradual and natural changes to which the ridge lines or glacier lines are subject for climate-induced variations».

For example, during the periodic reconnaissance of the border pillars, in 2000, a deviation of the watershed line was observed due to the retreat of the corresponding glacier. Following this transformation of the topography of the places, a modification of the boundary line was agreed between the two neighboring states. The effects of the withdrawal of the glacier are clearly highlighted by the Swiss Swisstopo, and the Italian IGMI maps as shown in the figures 4 and 5 and in the photos in figure 6 and 7 below.

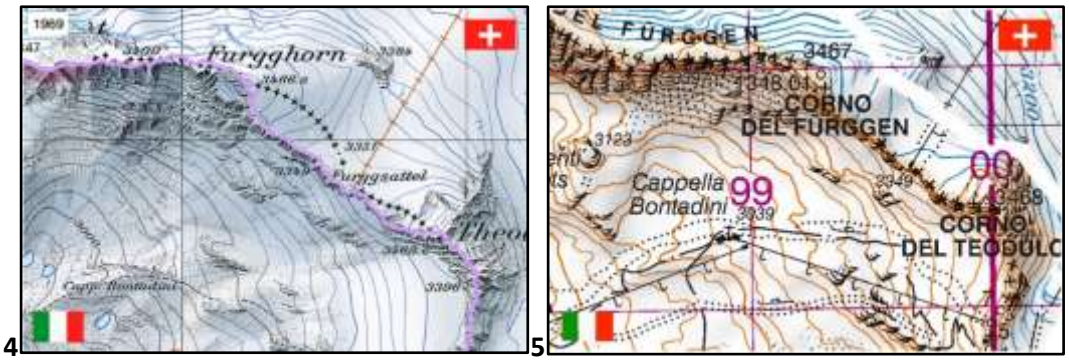

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Figure 4: Example of variation of the current boundary line (purple line) on the Swisstopo Map, compared to the indicated 1940 line (black crosses)

Figure 5: The same example of variation of the current corrected boundary line, indicated by continuous black crosses, as results today on the Official Topographic Map of Italy1:50,000, sheet no. 71 – Monte Rosa (2018 edition).

6 7

Figure 6: View on Monte Palla Bianca from the Vedretta della Croda in 1922

Figure 7: View on Monte Palla Bianca from the Vedretta della Croda in 2012

(Photographs –IGMI, Italy)

Final Remarks

At the end of these short notes, it should be dutifully noted that the idea of a «moving borders», linked to the cases previously illustrated, takes on an exceptional dimension in the collective imagination. The measure appears innovative because of the adjective «moving» that no one would have thought of associating with the term «border».

For the delimitation of properties in the most ancient civilizations, the border was materialized with a line, associated with the idea of "static", "fixity", "immovability", up to taking on a dimension of sacredness, introduced by the Etruscans and amplified by the Romans, with the creation of the god Terminus, in defense of private property. It is perhaps for this so important tradition, from which the laws of all modern states were inspired, that the provision named «moving borders» appears even more significant, precisely because it was born in the same land where the god Terminus was born and celebrated. The direct heirs

of the culture that had elevated the concept of the border on a sacred plan have in fact demolished its sacredness and sanctioned its variability over time.

8. BOUNDARY INSTABILITY DUE TO DYNAMIC PLATE MOVEMENT

Don Grant and Bill Robertson elaborate on this issue in two chapters of the publication, using practical data surveyed by Vince Belgrave during a revisit of the Iraq-Kuwait boundary 20 years after the original boundary demarcation, facing significant changes regarding location of boundary pillars and regarding the boundary geodetic reference points.
The movements of tectonic plates are typically several centimetres per year. An accuracy of several centimetres may be sought at the time a modern boundary is defined, in which case it may take only a few years of tectonic plate movement to exceed the survey threshold. The potential problem of boundary movement may exceed several metres per century.
The mechanism to resolve this situation would be to renegotiate a boundary that had been thought to be resolved. A better approach would be to consider this scenario at the outset and define the boundary in such a way that future disputes are avoided.
International boundary lines on land cross tectonic plate boundaries (Figure 8). Over time, straight lines could have a slowly developing offset or step in the formerly straight boundary line. This may occur either slowly as a result of gradual tectonic movement of a few centimetres per year, or suddenly as a result of a major earthquake. We see in Figure 8 that he tectonic plate boundary between the Arabian plate and the Eurasian plate crosses the international land boundaries of Iran-Iraq, Iraq-Turkey and Turkey-Syria while the Arabian and African tectonic boundary crosses the land boundaries of Syria-Lebanon, , Israel-Jordan, Eritrea-Ethiopia and Ethiopia-Djibouti.

Figure 8: Complex relationships between the boundaries of the Arabian tectonic plate (plate boundaries shown in white) and international boundaries in the region (shown in purple). (Retrieved from http://www.sonel.org/-Horizontal-land-movements-.html)

The historic option for managing long term boundary positions has been to assume the stability of boundaries over time. This approach works until earth movements are of such magnitude that ad hoc local solutions no longer suffice. The serious disadvantage of accepting historic positioning is that the coordinated positions become increasingly at

variance with the modern measuring capability of users. In addition, differential tectonic movement across the boundary line can cause ambiguity and dispute.

If the boundary is defined by the positions of monuments or physical features, then the boundary will, in effect, move with the tectonic plate. This will cause the least disruption to management of the boundary because there will be no apparent movement.

However natural features can move in relation to the local environment and boundary monuments can be damaged or destroyed. In this case, a boundary maintenance program is likely to recommend reinstatement. If this reinstatement relies on historical survey measurements or coordinates, combined with modern global positioning technology, then ambiguities in interpretation and survey conflicts may result. An alternative is to establish a plate fixed geodetic datum to define the boundary coordinates. This means that the boundary will not appear to move in relation to the local landscape while allowing unambiguous reinstatement of damaged or destroyed boundary monuments using the geodetic datum. This option however places great reliance on the geodetic datum itself, which must be maintained to ensure that it remains accessible and useable.

As noted above, there are two options for establishing a plate fixed geodetic datum: (1) establish a geodetic mark based network in general alignment with the ITRF and rely on the defined coordinates of one or more primary control stations to define the datum. (2) specify an ITRF and a reference epoch. For example, ITRF2014 at 1 January 2014. Option 2 provides more long term security because the international community protects the definition of International Terrestrial Reference Frames, including precise transformations from each ITRF to the next one. This option requires an accurate connection, ideally at the few centimetre level at least, between the geodetic network used to measure and monitor the boundary, and the ITRF used to define it.

It should be noted that each of these plate-fixed options will, over time, result in the boundary coordinates becoming increasingly out-of-terms with local surveying and mapping systems including geospatial datasets and personal positioning devices. However, provided that accurate transformations are available between the reference frame of the definitive boundary coordinates, and the more commonly used coordinate systems, this issue is manageable.

Conclusions

Grant concluded that the form of defining modern international boundaries can vary but nevertheless the negotiations for delimitation, demarcation and maintenance should take into account the long-term characteristics of the geodetic datum used to support or define the boundary. This will include consideration of: (1) the global rather than local nature of modern geodetic datums, (2) the ability to define coordinate reference frames with an accuracy of a few centimetres or better, (3) the impact of tectonic plate motion and other forms of earth deformation on geodetic systems, (4) the increasing use and security of a Global Geodetic Reference Frame (GGRF), (5) the need for a program for boundary and geodetic datum maintenance in terms of the GGRF, and (6) mechanisms for maintaining

alignment between boundary coordinates and other survey and geospatial datasets in use at each jurisdiction.

According to Robertson high-quality geo-positioning and accurate areal and locational calculations within each national border are required. Currently, there is a great lack of consistency, and exactness in many international boundaries. This makes them ill-suited to cope with the sea change of new geo-positioning technology as well as future user needs and demands. The challenges ahead are to review and transform the existing international boundaries, in order to better serve users' positioning requirements and future needs.

In today's global positioning world, the delimitation, demarcation, and maintenance of international boundaries can in the future be improved by being connected to a regional densification of ITRF. This could well be the densification of ITRF through the national primary control system. It would allow international boundary coordinates to be connected to an epoch of the ITRF and upgraded regularly through the national geodetic system. This would ensure that international boundary positions can readily be brought into terms with satellite positioning for all user applications. Taking into account the movement of tectonic plates, the increasing accuracy of even hand-held and UAV-based receivers, will ideally require the regular upgrading of all international boundary coordinates every decade. For future consistency, the ellipsoid, datum and coordinates for calculations, as well as the long-term adjustment to the ITRF could be a standard requirement in the technical specifications of all future boundary demarcation agreements.

A desk reconnaissance system should be a prerequisite for effective longer term planning. A first step would be a collaborative assessment of the existing surveying condition and the standards of international boundaries. A comprehensive inventory and data base would provide a sound basis for developing a collaborative strategy for connections and transformation to ITRF. Follow-up analysis and research would assist in the development of strategic advice and recommendations by FIG for the long-term survey upgrading and maintenance of international boundaries.

Such a survey would provide sound input into the current UN-GGIM initiative and fit well into the role and organizational capability of FIG. The inventory information could cover, for example, items such as the lengths of boundaries demarcated, coordinated, connected to a datum, and plans for upgrading international boundary positioning. The findings of such a survey would put FIG in a good position to contribute to UN-GGIM, IGiF in relation to the development of an ITRF-compatible format for ensuring the currency and authority of international boundary coordinates.

9. CONCLUSIONS

The best way to achieve the ultimate goal of ensuring the stability and permanence of international boundaries in order to support peace worldwide is to fix the boundary lines by consensually agreed, accurate coordinates on well-maintained internationally agreed upon geodetic reference systems.

This is an ideal professional solution for international boundaries on land and in the seas. This approach can be implemented after the (potential) settlement of all international boundary disputes.

However, there are still natural dynamic cases in which the ground through which the boundary line is delimited is still unstable. In some of these cases, such as rivers and glacier crests, the boundary line should not have been delimited in the first place. However, since many boundary lines were already delimited in such places, these cases should be dealt with, and they are discussed in this article. On the other hand, the movement of tectonic plates does not ensure the stability of any location worldwide. Therefore, an approach to deal with this issue is recommended.

The general trend regarding delimitation of international boundaries in lakes is to fix the boundary line. Such delimitation may be fixed by coordinates, either before the boundary agreement is signed or at a later time following detailed delimitation on maps and an agreed unequivocal definition of the process of producing the agreed coordinates. The boundary line should be fixed and detached from any change in the coast lines of the lake. The regulation regarding the rights of access to the water and the rights of use should be agreed upon in a separate arrangement.

According to the traditional approach regarding boundary lines in rivers, although it is not a formal convention or a customary law, the boundary line follows gradual natural changes in the river bed and does not follow sudden changes, unless otherwise agreed upon. In the case of artificial man-made changes in the river the boundary line remains in its original location.

As discussed in the article the combination of global warming and global population growth during the last century, and mainly since the middle of the 20th, century has had a dramatic detrimental effect on rivers all over the world, including many water projects, e.g., reducing the water volume in rivers, constructing dams and reservoirs, as well as hydro-electric power stations and industries, which divert the river's flow. These activities have changed the natural behavior of many rivers, including boundary-rivers; thus, they have changed the basis of the traditional methodology regarding the perception that the boundary line follows the "natural" change in the river. Since the changes in the boundary line, as a result of following the changes in the river are a significant contributor to instability of boundary lines all over the world, the author suggests that it is time to re-consider the traditional boundary doctrine regarding rivers. An alternative option may be to fix the boundary lines in rivers and to deal with changes in the rivers regarding access to the water and the use of water rights in separate regulatory agreements.

However, the case of boundary lines on glaciers differs from the other cases. Unlike the case of a river that moves to a random or undefined line, the water-shed line along the icy crest moves to the watershed line along the rocky crest after the ice melts. The rocky water shed line can also be defined accurately. Hence, actually, it is a choice between two solid lines (with an intermediate random option between them). The two bordering states must decide and agree whether to fix the original boundary line or leave it open to be changed locally down to the rocky line.

Regarding the boundary instability due to tectonic plate movement, no magic solution exists; however, changes must be monitored over time, and the geodetic reference must be properly managed dynamically in order to properly adjust the coordinates of the boundary line. It is recommended to migrate from a local boundary datum to a dynamic well-supported regional ITRF reference.

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Dr. **Haim Srebro** has been involved as a leading figure in international land and maritime boundary delimitations and demarcations since 1974, and signed a few international boundary agreements. He was the Director General of the Survey of Israel from 2003 to 2012. Since 1994 he is co-chair of the Israel-Jordan Joint Team of Experts regarding the delimitation, demarcation, documentation and maintenance of the international boundary. He founded the FIG Working Group on International Boundaries and chaired it during the years 2011-2014. He edited FIG Publication No. 59 on International Boundary Making as vice-chair of Commission 1. He was Congress Director of FIG WW 2009 in Eilat. Currently, he chairs the FIG Working Group on International Boundaries Settlement and Demarcation. He edited FIG Publication NO 76 (2020). He holds a BSc in Civil Engineering and MSc in Geodetic Engineering from the Technion (IIT), and a PhD in Geography from Bar-Ilan University. He is a senior consultant on mapping and boundaries and author of books and many papers on these subjects. He is active in FIG since 2004. Haim.srebro@gmail.com