Mapping in Support of Frontier Arbitration: Coordinates

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Introduction

Throughout the whole process of the arbitration of a land frontier dispute it is necessary to refer to locations as unequivocally as possible. While researching the history of the case, preparing written pleadings, presenting oral evidence, judging the case, preparing the judgement and documenting the delimitation, significant places appearing in documents or on maps have to be carefully defined. The main method of doing this is by the use of coordinates, usually geographical coordinates, i.e. latitude and longitude.

Geographical coordinates are an arbitrary mathematical device and unless their technical limitations are understood they can mislead, as well as assist, those engaged in frontier arbitration. If some of what follows seems obvious to the reader, I apologise. Nevertheless, I have found that the fundamental problems of using coordinates are often not understood by those involved in arbitrations and to explain them it is necessary to go back to basics.

Geographical Coordinates

Geographical coordinates tend to be regarded by laymen as absolutes, irrevocably defining a spot on the earth. Surveyors and cartographers who work with them know that this is not so and the following paragraph explains why.

Any basic coordinate system is made up of distances from two axes at right angles which start at an arbitrary datum point. Perhaps the simplest example is the town map which is divided in to squares labelled A, B. C... upwards along the left hand side (one axis) and 1, 2, 3... along the bottom (another axis). The datum is square Al. Locations are defined by measurement along the two axes as, for example, D5. Clearly, if the town grows to the south west and the datum square Al is moved accordingly, the coordinates of all the points in the town are changed. Point D5 could become E6 on the new edition of the plan. The same applies to graticules of geographical coordinates on maps since all such graticules depend on the selection of an arbitrary datum. Confusion arises because all geographical coordinate systems are approximately based on the Greenwich meridian[1] and the equator as axes so that values are consistent at small scales such as are used for atlas maps. However, the coordinate system of each country or group of countries is based on a local datum. Since these datums were usually set up in the last century, their latitude and longitude were determined in relation to Greenwich and the equator by relatively imprecise astronomical methods and they are not in sympathy with one another. Where two such systems overlap, there will be two different sets of geographical coordinates for each point on the ground, neither of which is necessarily the 'right' set. In many countries the datum has been changed as knowledge improved, so that maps of one area, but of different editions or dates, will give different coordinates for one place on the map.

Variation in the choice of datum is the easiest to comprehend of the causes of inconsistency between geographical coordinate systems but it is not the only one. Unlike the town plan cited above which treats the earth as flat, geographical coordinates take in to account that the earth is shaped as a spheroid (a sphere slightly flattened at the poles). Each geographical coordinate system makes its own assumptions about the size and flattening of the spheroid which in turn has a significant effect on the coordinates.

The coordinates are also affected by the fact that the earth is not actually a uniform spheroid but is a lumpy geoid of irregular make-up. This means that, particularly near mountains, the plumb line does not point to the centre of the earth, which in turn affects astronomical observations which are made in relation to the horizontal defined by a spirit level, causing distortion to geographical coordinates based on them. Even the earth's axis is not fixed and polar wandering moves the position of the equator. Finally, a major factor is that surveyors and cartographers do sometimes make mistakes in observing and calculating positions, or plotting the graticule lines on maps from which geographical coordinates are measured.

The older the map the more likely it is that the graticule of geographical coordinates will be based on unsatisfactory field observations. Before the advent of wireless time signals, longitude, the measurement of which depends on knowing the time accurately, was particularly susceptible to error.

Grid Coordinates

In addition to a graticule of geographical coordinates, more modern maps often carry a more prominent, rectangular, grid of coordinates, usually consisting of squares with a side of 1, 10 or 100km depending on scale. This was originally a military development but it is now much more general and will be familiar from Ordnance Survey maps. Although there has been some standardisation on the Universal Transverse Mercator system, these grid coordinates have even more sources than geographicals and are even more arbitrary in choice of datum and other parameters. They are plane coordinates so are only an approximate fit to the curved earth and each grid only covers a relatively small area. At overlaps between grids, military maps show two or even three grids. Except for use over a small local area these grids are best avoided for arbitration work as they lack permanence and can lead to confusion. Gridded maps may not have the graticule lines on their face but will almost certainly have graticule ticks and values around the margin so that a graticule of latitude and longitude can be constructed.

Global Positioning System (GPS)

Recent advances in satellite and computer technology have brought a remarkable change to the determination of position. GPS, operated by the United States, originally for military purposes, is now becoming widely known for its ability to give accurate navigational fixes world-wide, using hand-held equipment. A more refined version has become the universal tool of surveyors, since it is possible to determine the geographical coordinates of a position to an accuracy of one metre, or better, in a very short time.[2] Of equal significance to the accuracy is that all coordinates from GPS are in the World Geodetic System (WGS). WGS is just another datum and set of defining parameters but it has been universally accepted so that all GPS results are always compatible with one another. At any one point the result of a GPS fix will always be the same. Thus the ideal solution of every point on the earth's surface having a unique set of geographic coordinates has been achieved.

Using GPS for accurate surveying is not quite as simple as I have made it sound as there are some technical problems, but they are solvable. There is the prospect in future of other nations operating similar systems on a commercial basis rather than as a by-product of a military need that could change. This should ensure continuity of the availability of a suitable system..

The advent of GPS has already revolutionised the demarcation of newly-established frontiers but it will be some time before it will have much impact on negotiations about existing frontiers or on arbitration cases. All the evidence in such cases is likely to come from pre-GPS sources and delimitation is still likely to be on pre-GPS maps. Care will still be needed in handling coordinates. Meanwhile survey departments world-wide are struggling to reconcile GPS coordinates, that are easily available to users, but which do not fit their existing maps, survey and cadastral records. The more advanced departments have initiated conversion schemes but it will be many years before all current mapping is compatible with WGS coordinates. Since older mapping and survey data is never likely to be converted, frontier arbitration proceedings will have to take in to account the existence of incompatible coordinate values for the foreseeable future.

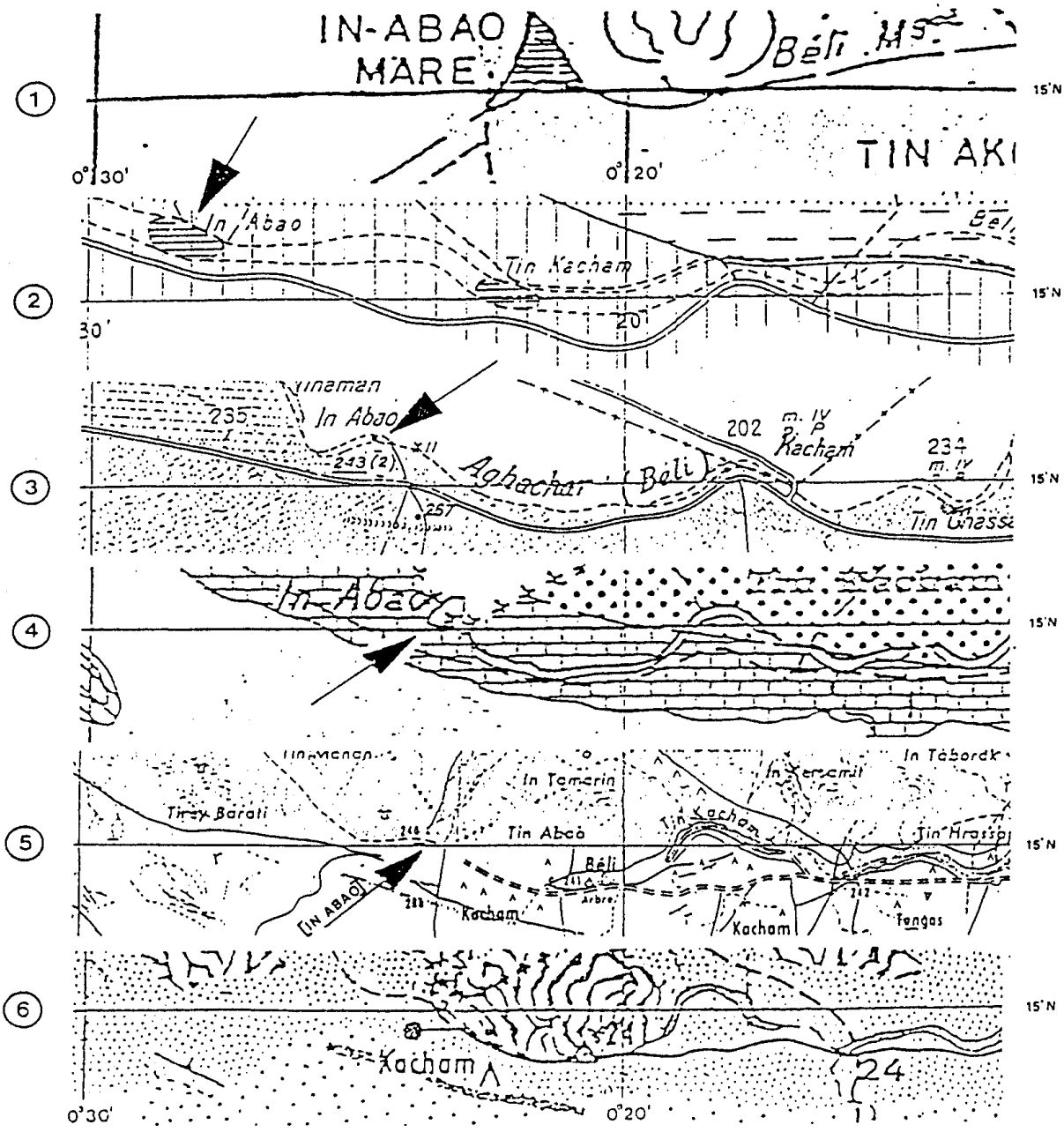
The Use and Abuse of Coordinates in Frontier Cases

In an earlier article in this series,[3] I analysed the maps used for delimitation on four cases as examples of a variety of approaches. The same four cases also provide an insight in to some of the various ways that coordinates have been treated during arbitration, delimitation and demarcation.

In the Burkina Faso-Mali Case the International Court of Justice met problems because the geographical coordinates of points along the border differed on the various maps produced as evidence. Included in the Judgement is a sketch map,[4] a copy of which is reproduced at Figure 1. This shows the location of the In Abao Pool on six maps in relation to latitude 15° 00'N and longitude 0° 20'W. The geographical coordinates vary by 6 minutes (11km) in longitude and 2.5 minutes (4km)

Figure 1: Extract from Burkina Faso-Mali Judgement

Position of the Pool of In Abao according to the various maps.



1 Blondel La Rougery Map, 1925
2 Map of the Federal Department of Mines and Geology, Nov 1953
3 Map of the Hydrological Service of French West Africa, Nov 1954
4 Geological Reconnaissance Map of Upper Volta, 1961
5 Map of West Africa on a scale of 1:200,000, 1960-1961
Site of In Abao indicated as 'Wet sand and alluvial deposits'
6 Map of French West Africa on a scale of 1:500,000, 1961
Note 'Kacham' appears at the site of In Abao indicated as 'Wet sands'

in latitude. The Judgement comments, not unreasonably:

> *"It is clear that the Chamber does not possess the necessary information to determine the exact geographical coordinates of the pool of In Abao."*

After further investigation the Judgement decides that:

> *"It will be for the Parties,...to fix the position of the pool of In Abao and to define two points lying on the same parallel of latitude, such that a straight line drawn between these points will divide the expanse of the pool in equal proportions between the Parties."*

Thus the difficulty with uncertain geographical coordinates led to a very unsatisfactory delimitation which could lead to intractable problems in demarcation. It seems to me that, because the Court could not decide on geographical coordinates for the pool, they felt themselves unable to properly delimit the boundary in its vicinity.

In fact, as shown above, there is no such thing as the *"exact geographical coordinates"* of the pool and the search for them was meaningless. What the Court actually needed was a way of exactly defining the location of the pool. This could almost certainly have been achieved, quite easily, by marking the position on one of the readily available air photographs of the area.

Despite the problems the Court had with geographical coordinates, its delimitation [5] confidently gives the position of turning points on the border to 1 second (30 metres) of latitude and longitude, without giving any indication of how these coordinates are derived. They are actually taken from one map of the area which the Court found the most useful of the maps at their disposal,[6] and which they used as a graphical support to the delimitation.

Although probably the best map available, it is really little more than a small scale, reconnaissance map, being prepared by graphical air survey based on sparse astronomical control. It would have been much more helpful to the practical users of the Judgement if it had included statements that the coordinates were derived from, and should only be used in conjunction with, one particular map and that the values given for the coordinates are unreliable and certainly do not approach the accuracy implied by quoting the values to one second.

In considering the El Salvador-Honduras case, the Court only had minor problems with geographical coordinates as they did not feature much in the evidence. The Court found that: *"There is a discrepancy between the contentions of the Parties as to the coordinates of latitude and longitude to define the position of the agreed tripoint.* [The start point of the border at the junction of El Salvador, Guatemala and Honduras] *It however appears that the different coordinates given by the Parties in fact designate the same point, the discrepancy resulting from the choice of a different datum; as explained below the Chamber will, when defining the boundary line, use the coordinates appropriate to the maps used to illustrate the Judgment."* [7]

The Judgement thus makes clear that the geographical coordinates that it uses in its delimitation [8] are only relevant to specific maps, which are all listed. It would have been a bonus if the Judgement had added a definition of the datum used and a warning against use of the coordinates in other contexts. The maps referred to are the US Defence Mapping Agency (DMA) 1:50,000 mapping of the area. These are modern maps and the quotation of the coordinates of turning points in the delimitation to one second (30 metres) is fully justified.

The Award in the Argentine-Chile (Palena) Case [9] does not use geographical coordinates except to define general areas of interest. For the precise indication of turning points in its delimitation it uses air photographs marked with a cross. This gives a very clear and positive location for the points while avoiding any confusion due to uncertainty about the geographical coordinates.

The demarcation of this boundary was undertaken by the arbitrator. This is unusual nowadays but was common practice in earlier times. The report of the demarcation [10] describes how the boundary was surveyed and *"the geographical position of each Boundary Post was determined in relation to the Mixed Commission triangulation, to third order accuracy."*

Because the boundary was in a remote area of the Andes, there was no link to the national surveys of Argentina or Chile. The Mixed Boundary Commission (joint Argentine-Chilean) had therefore established survey control in the area, based on an arbitrary local datum. This survey control, which was used for the demarcation, was adequate for the

task but is of a relatively low standard of accuracy. In view of the probable effect of the Andes on the deviation of the vertical it is almost certain to give very different coordinates to WGS. Fortunately most of the concrete control points and the concrete and iron boundary posts will have survived and planned re-observation with GPS on a few points will enable the geographical coordinates of all the boundary posts to be adjusted. However, it will, presumably, require a formal agreement between the two countries to change the coordinates which at present represent the definition of the boundary posts.

In other areas the resolution of such problems may not be so straightforward. For example, the boundary points on the Qatar-Saudi Arabia boundary are defined by coordinates on the Saudi Arabian datum, which has been used for much, but not all, modern surveying and mapping in Arabia. This datum has now been superseded by WGS. It is possible that none of the survey control markers in the border region have survived, which will make recreating the boundary a problem. GPS will be of little assistance as its relation to the Saudi Arabian datum in the area will be difficult to determine.

The delimitation of the boundary between Israel and Jordan is a model of how such a task should be undertaken. Clearly professional surveying and cartographic staff from both sides were allowed to specify how the practical side of delimitation should be achieved. As in the Palena Case, the delimitation does not describe the boundary in terms of coordinates but as photographic images, in this case on orthophotomaps. The survey task of the demarcators is then very clearly specified. It is stated that:

> *"The boundary pillars shall be defined in a list of geographic and UTM coordinates based on the joint boundary datum (IJBD 94) to be agreed by the Joint Team of Experts appointed by the Parties using Global Positioning System measurements ... This list of coordinates ... shall be binding and shall take precedence over the maps as to the location of the boundary line of this sector."* [11]

This approach is undoubtedly the way ahead for boundary delimitation and demarcation.

Conclusion

The message to those engaged in frontier arbitration is to treat latitudes and longitudes with care and circumspection. Geographical coordinates are most likely to be read from maps produced as evidence but may also come from earlier documents about the frontier or the results of field surveys. It is likely that many of these sources will be quite old and from a wide variety of sources. It is important to remember that the coordinates from a map, document or survey are only valid as far as that item is concerned and cannot, with safety, be applied to another item, unless a link has been firmly established by technical tests or evidence. A coincidence of coordinates for one point on two maps does not necessarily mean that all points on the maps are in sympathy. When quoting coordinates, especially in the delimitation section of a Judgement, it is most important to indicate their source and warn that they should not be used in any other context.

Notes

[1] This was not always so. Many countries formerly used other reference longitudes. Longitudes on Russian maps, for example, were based on Pulkova until well in to this century.

[2] For further details of GPS and its use on boundary work see: Adler, R. (1995) *Positioning and Mapping Land Boundaries*, Boundary and Territory Briefing, 2, 1, Durham; International Boundaries Research Unit: paragraph 2.5.

[3] Rushworth, D. (1996) 'Mapping in Support of Frontier Arbitration: Maps for Delimitation', *Boundary and Security Bulletin*, 4, 3, Durham; International Boundaries Research Unit.

[4] International Court of Justice, (1986) *Case concerning the 'Frontier Dispute Burkina Faso-Mali'*, Judgement: Sketch-Map No 5, page 89.

[5] *Ibid*. Para 179, page 99.

[6] *Ibid*. Para 175, page 98. The map is a reduction to 1:400,000 of IGN Map of West Africa,1:200,000, various sheets 1958-1961. Map (5) on Figure 1 is an extract of this map. Although the Judgement at a footnote on page 98 implies otherwise, the sealed copies, as well as the published copies, are at 1:400,000 scale.

[7] International Court of Justice, (1992) *Case concerning the 'Land, Island and Maritime Frontier Dispute El Salvador-Honduras: Nicaragua intervening'*, Judgement, para 68, page 54.

[8] Ibid. Paras 425-431, pages 263-268.

[9] *Award of Her Majesty Queen Elizabeth II for the Arbitration of a Controversy between Argentina and Chile*, (1965) London: UK Foreign Office.

[10] *Report by the Director of Military Survey to the Government of the UK on the Demarcation Mission of the Argentine-Chile Boundary*, (1967) London: UK Ministry of Defence, para 12, page 11.

[11] *Treaty of Peace between Israel and Jordan*, Arava Border Crossing, October 1944, Annex l(a).

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