The Analysis of Geopolitics: Reconceptualizing International Borders Through the Application of GIS[1]

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ABSTRACT
Over the past 15 years there has been a renewed attention to the role and impact of geography in the study of international relations. Much of this is related to the "new geopolitics" which treats geography as an essential part of the context of possibilities and constraints that face foreign policy decision makers. Based on earlier work which conceptualized and described international borders (Starr and Most 1976), this study seeks to establish a major reconceptualization and revision of how borders may be seen and measured. The use of GIS (Geographic Information Systems) will permit a much fuller and clearer specification of borders by allowing us to talk about the specific qualities of borders in terms of opportunity and willingness: ease of interaction and salience, respectively. The reconceptualization will lead to the creation of a dataset which will permit us to go beyond simply observing the number of borders a state possesses, whether or not a border existed between two states, or the length of that border.

Paper prepared for presentation at the Southern Political Science Association Annual Meeting, Atlanta, November 6-9, 1996.

GEOPOLITICS, BORDERS AND IR: A ***BRIEF*** INTRODUCTION

A review of the literature on war, militarized disputes, enduring rivalries, and alliances, indicates that over the past 15-20 years there has been a renewed attention to the role and impact of geography in the study of international relations.[2] Much of this is related to the "new geopolitics" which treats geography as an essential part of the context of possibilities and constraints that face foreign policy decision makers (see Starr 1991; Ward 1992; Goertz and Diehl 1992; and even Goertz 1994). Studies of the diffusion of behavioral phenomena as well as the investigation of the relationships between proximity, contiguity, location and territory to international interactions, have burgeoned. These activities by students of international relations have paralleled those of geographers who are focusing on a "new geopolitics" based on the possibilities that the geopolitical environment provide to human decision makers. Based on the possibilism of Harold and Margaret Sprout, among others, the work of such geographers has been most clearly found in the journal *Political Geography.*

Much of my own work has addressed questions which fit within this broad geopolitical perspective. Beginning with the development of the opportunity and willingness framework (Starr 1978), I have engaged in collaborative research which has sought both to refine these concepts as well as specify the relationships between them (e.g. Most and Starr 1989; Cioffi-Revilla and Starr 1995). These concepts have also been clarified through efforts to operationalize them in the study of international political phenomena. The latter investigations include the study of the diffusion of international phenomena, especially violent conflict (e.g. Most and Starr 1980; Siverson and Starr 1991). Although this framework has included the study of alliances, the central feature of the analyses has been a focus on the nature and effects of spatial proximity as operationalized by international borders. Simply, the present paper can be seen as a concept clarification exercise— its aim is to revise and reconceptualize how we think about borders and how they should be measured.

While there are many facets to a geopolitical approach to international relations (e.g. Starr 1991; Ward 1992), borders have been of primary interest to, and the main focus of, geopolitical scholarship. For example, as one important component in the mapping of factors related to the onset of war, the Correlates of War project has developed the most extensive and complete dataset on borders available for international systemic actors since 1816 (e.g. see Gochman 1992, for a description of the COW measurement rules; see also Starr and Most 1976). Borders have been studied as part of the analysis of many of the central concerns of international relations. A brief list of these concerns would include: the number and types of interactions among states; interdependence among states, within regional groupings and the level of interdependence within the international system as a whole; regional integration; the probability of war among states; the diffusion of war and other forms of international conflict; the diffusion of additional international phenomena, such as the spread of democracy; understanding why and how territory affects the onset of war; the processes underlying the lack of war between pairs of democracies; the effects of alliances; the question of international regions and the structure of the international system.

CONCEPTUALIZING BORDERS

Thus, the location of states, their proximity to one another, and especially whether or not they share "borders," emerges time and again as a key variable in studies of international conflict phenomena: from major power general war, to the diffusion of international conflict, to the analysis of peace between pairs of democracies. But how exactly do borders affect international interaction?

Clearly, a key dimension for many researchers is proximity (see for example, Gochman's 1992 discussion of borders as they relate to the overall COW project). My own diffusion research moved to the study of borders after concluding that the diffusion of certain phenomena could only be studied by looking at units that were "relevant" to one another— and that such relevance could be indicated by geographical proximity (see also the recent work of Lemke— 1995, 1996). Proximity, in turn, could be operationalized through "borders." Borders were seen as important indicators of proximity, and thus relevance, because they had important relationships to both the opportunity and willingness of state actors. Thus, in Starr and Most (1976) we conceptualized borders in terms of both opportunity and willingness. One key aspect of borders is that they affect the interaction opportunities of states, constraining or expanding the possibilities of interaction that are available to them. States that share borders will tend to have a greater ease of interaction with one another, and thus will tend to have greater number of interactions. This idea developed from multidisciplinary sources, such as economist Kenneth Boulding's (1962) concept of the loss-of-strength gradient; or geographer G.K. Zipf's (1949) "law of least effort."

The important issue raised here is that borders create the opportunity for interaction (see Starr and Most 1976, Most and Starr 1980, and Siverson and Starr 1991 for a full discussion of geographic opportunity). Such opportunity might be seen in terms of the number of other countries with which any single state has interaction opportunities. It might also be seen in the degree to which such opportunity exists between any particular pair of states. So, for example, Wesley (1962) argues that the length of a common border between two countries is a better measure of "geographic opportunity" than simply the number of borders. Longer borders, he argues, provide for greater opportunity than short borders. And, presaging the GIS discussion to be presented, he goes on to suggest than length should be measured not in "actual physical length" but in terms of population units. I have argued that this view of borders— as opportunities for interaction— gets at the important conceptual core of proximity in a way that other measures of "distance" do not. Such measures have included the use of the air mileage between the capitals of states to measure distance (e.g. Gleditsch and Singer 1975, Garnham 1976).

Secondly, borders also have an impact on the willingness of decision makers to choose certain policy options, in that they act as indicators of areas of great importance or salience. Because other states are close, having greater ease of interaction and the ability to bring military capabilities to bear, they are also key areas of external cues (or diffusion). Accordingly, activities in these areas are particularly worrisome, can create uncertainty, and thus deserve attention. The notion that changes in bordering areas create uncertainty because of their proximity was based on arguments developed by Midlarsky (e.g. 1970, 1975).

Starr and Most (1976:10) were also particularly concerned with the "roles that different types of borders appear to play" in war involvement. Different types of border might have differential impacts on both opportunity and willingness. Thus, borders were differentiated in terms of homeland borders and borders generated by colonial territories. This differentiation allowed us to test whether all territory was seen as equally important, or whether homeland territory generated greater willingness than more distantly held colonial/imperial territories. Implicitly tested in such analyses was the notion that it was homeland territory *per se,* that was important: that the proximity of <u>any</u> homeland territory of one state to any homeland territory of another state was the important factor. While some analyses indicated that this was probably the case, analyses also demonstrated the strong impact of colonial territorial borders on the diffusion of war. Simply, colonial territories were responsible for creating a greater number of <u>opportunities</u> for conflictual interaction.[3] We thus concluded that we had been correct in the inclusion of colonial borders (a twist unique to IR research in our original border dataset). Starr and Most (1976) also distinguished between land-based contiguity and across-water proximity. Again, such a distinction <u>implicitly</u> dealt with possible variations in ease of interaction and salience.

The present project seeks to build upon these two dimensions of borders as indicators of proximity, to revise and reconceptualize how borders may be seen and measured. The use of GIS (Geographic Information Systems) will permit a much fuller and clearer specification of borders by allowing us to talk about the specific qualities of borders in terms of opportunity and willingness. The reconceptualization will permit us to go beyond simply observing the number of borders a state possesses, whether or not a border existed between two states, or the length of that border. By so doing, a number of questions raised in studying the issues noted above can now be addressed.

RECONCEPTUALIZING BORDERS THROUGH THE APPLICATION OF *GIS*

Geographic Information Systems: A Brief Introduction [4]

Geographic information systems, developed through the early to mid-1960s, are now the focus of a large literature produced by geographers and regional scientists.[5] As could be expected, there are many approaches and perspectives on GIS. However, some simple definitions can be provided:

- A GIS is designed for the collection, storage and analysis of objects and phenomena where geographic location is an important characteristic or critical to the analysis (Aronoff, 1989, 1).
- ...a GIS is an organized collection of computer hardware, software, and geographic data designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information (Dangermond 1992, 11-12).

It is important to understand that a GIS is a <u>tool</u>, founded on a variety of computer technologies, that permits the handling of data concerned with the location— or, more broadly, the <u>spatiality</u>—

of physical phenomena and human artifacts. A GIS permits the integration of data about the spatiality of phenomena along with data about other characteristics of those phenomena. More technically (Dangermond 1992, 12):

> GISs can store geographically referenced (cartographic or spatial) data in a raster (grid or cellular-based) data structure or in an *x,y* coordinate reference-based (vector) data structure as points (nodes), lines (arcs), and polygons (bounded by arcs, inclosing an area)... GISs make use of a variety of coordinate referencing systems to locate features on the earth relative to others; these coordinate systems, in turn, make use of a variety of map projections to transform earth references onto a two-dimensional surface (the map). Modern GISs also typically store the topology (spatial relationships between connecting or adjacent features) of mapped features in the database. The information pertaining to the various spatial features... is stored typically as attributes (characteristics of a mapped feature) in tabular files linked to the feature often in special database management systems (DBMSs).

In order to perform the functions noted above, and to be considered a true GIS— having the ability to create new information that goes beyond computer mapping— a system must include the following four major components (Marble, 1990:10):

1) A data input subsystem which collects and/or processes spatial data derived from existing maps, remote sensors, etc.
2) A data storage and retrieval susbsystem which organizes the spatial data in a form which permits it to be quickly retrieved by the user for subsequent analysis.
3) A data manipulation and analysis subsystem which performs a variety of tasks such as changing the form of the data through user-defined aggregation rules or producing estimates of parameters and constraints for various space-time organization or simulation models.
4) A data reporting subsystem which is capable of displaying all or part of the original database as well as manipulated data and the output from spatial models in tabular or map form.

It is important, as noted, to see that these four components take a GIS beyond mere computer mapping. According to Cowen (1990, 57), the heart of a GIS system is its ability to overlay various layers or coverages of data so that the GIS would have "created new information rather than just have retrieved previously encoded information."

The ARC/INFO Geographic Information System[6]

ARC/INFO, developed and supplied by Environmental Systems Research Institute, Inc. (ESRI), is one of the most widespread commercial GISs in use globally. Its strengths, in part, reside in its ability to integrate many kinds of data, as well as "an open architecture which allows it to be linked to a number of relational database management systems" (Peuquet and Marble 1990b, 91). ARC/INFO employs a "georelational" approach, which abstracts "geographic information into a series of independently defined layers or coverages, each representing a selected set of closely associated geographic features (e.g., roads, streams, and forest stands)" (ESRI 1992, 14). Another advantage of ARC/INFO is the flexibility it provides, allowing users to employ any combination of features across any combination of coverages to capture the complexity required by the research in question.

The research project discussed below is based on the ARC/INFO GIS housed in the Humanities and Social Sciences Computing Lab at the University of South Carolina. Data for this project is from the Digital Chart of the World (DCW), produced by ESRI for the Defense Mapping Agency in 1992. The data contained in the DCW was derived primarily from maps in the Defense Mapping Agency Operational Navigation Chart series that were used to generate a 1:1,000,000-scale vector database covering the entire surface of the earth. Because of the enormous spatial areas and quantities of data associated with the DCW, data is organized and stored in 2,094 five degree (latitude-longitude) square tiles. All data, at the 1:1,000,000 scale, for a given area of the world is stored in its corresponding data tile.

[Table 1. about here]

The large scale database consists of the sixteen layers of data presented in Table 1. These layers contain data ranging from physical characteristics such as drainage networks, hypsography (elevation and topographic relief), and land cover, to man-made features such as road networks, railroad networks, and aeronautical data. Within each of the data layers, attributes such as length, area, and perimeter, to name but a few, are assigned to their corresponding feature. A seventeenth layer, the Data Quality layer, provides information on the particular source of data for a given tile and when that source was last updated.[7]

Layers of data in the DCW are organized into four types of coverages depending on the characteristics of a particular feature: point, line, polygon, and net. Point coverages are used for features such as airport location; line coverages are used for roads; and polygon coverages are used for vegetation coverage. The net coverage can contain polygon, linear, and point features. Features such as Political Units are frequently depicted as both polygons and outlined as a linear feature. Any specific class of features is not limited to one type of coverage organization. For example, cities and roads both have area, and as such can be organized as polygons and as points or lines respectively. However, all features are not necessarily organized by all of their possibilities. In the DCW, large urban areas are stored as polygons and points but the road coverage is stored only as a line coverage.[8] This discussion is only the most elementary introduction to ARC/INFO. Several of the data types and data analysis tools available in the ARC/INFO GIS will be illustrated below in describing its application to the study of interstate borders.

ARC/INFO and the Conceptualization of Borders

Starr and Bain (1995) describe how various coverages within the ARC/INFO system were used to revisit the two dimensions of borders discussed above: opportunity (opportunity for interaction as ease of interaction) and willingness (as salience). Rather than simply indicating the presence or absence of a contiguous land border (as in the original Starr and Most [1976] dataset or the later, and more comprehensive, COW dataset), the ARC/INFO coverages allowed for the actual operationalization and measurement of opportunity and willingness.[9] In subsequent work (with the research assistance of Deb Thomas and Richard Deal), the specific methodology used for extracting and combining the border data from the various ARC/INFO coverages has changed substantially. However, the data sources, coverages, and overall criteria for determining the opportunity for interaction and salience did not vary. Thus, I will review the measurement indicators developed by Starr and Bain.

Opportunity for Interaction (Ease of Interaction) Using data available in the DCW's data layers indexes indexes were constructed for both ease of interaction and salience. These indexes aggregate values generated from ARC/INFO. They can be used to characterize any border or border segment on the globe. After reviewing all the variables within all of the layers, three were selected to create an index of "ease of interaction." The first variable looked for the presence or absence of roads within the locations being studied. Roads included multi-lane divided roads, as well as primary and secondary roads (Layer 4, Road Layer, RDLINE).[10] The second variable was the presence or absence of railroads (Layer 3, Railroad Layer, RRLINE). *Overhead #1,* for example, indicates the network of roads and railroads for Israel and its environs." The third variable involved the slope of an area, which was based on the elevation values of contour lines (in mean feet above sea level; Layer 8, Hypsography Layer, HYNET), and was derived from a digital terrain model by converting the hypsography into a triangulated irregular network (see *Overhead #2).* Each of these values was investigated for a buffer area of 10,000 meters on each side of all international borders.

The methodology used by Starr and Bain involved the use of hexagons, and the combined density of the different coverages for roads, railroads and hypsography produced by a polygon attribute table for each hexagon. This generated a metric (an ease of interaction index running from 0 to 373) whereby high "saturation" or density indicated the greatest ease of interaction. The results were presented in Starr and Bain (1995) in black and white figures; the color representation from which the black and white figures were derived, can be seen in *Overhead #3.* The least saturated hexagons are those which are most difficult to move across, indicated in *Overhead #3* by the very light tan hexagons. The most heavily saturated hexagons are the most easily traversed, and are represented by the red and dark orange hexagons.

However, despite several advantages to the use of hexagons, this methodology increased both the computing capacity and time required for generating the data from ARC/INFO. A methodology using the vector data directly was developed which appeared to simplify the generation of the data considerably, while producing roughly analogous results.[12] The revised map of opportunity for interaction is seen in *Overhead #4.* In this formulation we simply noted the presence or absence of roads and railroads (rather than the saturation of a hexagon), and represented the hypsography or slope as follows: 1 if the slope was 0-5 degrees, 2 if the slope was 5-20 degrees, and 3 if it was greater than 20. This created a simple 1 to 4 index, with 4 representing the greatest ease of interaction, and 1 the most difficult areas to move across.[13]

Overheads #3 and #4 are important in demonstrating that the ease of interaction can vary along any single border that a state might have with a contiguous neighbor. The opportunity for interaction variable can be used to indicate this variation along any single border (or "arc", for example Israel's border with Lebanon). This would capture the variation that might occur on a very long border— any particular portion of a border can be thus be characterized as to its degree of permeability. While not done in either *Overhead #3 or #4,* the opportunity for interaction could also be averaged along an entire arc or border in order to classify that border as one with high, medium, or low ease of interaction; (that is, we could compare the average ease of interaction along Israel's border with Egypt to that of the border with Lebanon). Thus, we are now able to go beyond the simple idea that in some way contiguity provides the possibility for interaction— while some parts of some borders would make this highly likely (possible), while other parts would make interaction much less likely (possible). We could make such judgments irregardless of the length of a border, or even the number of different borders (or "arcs") that a state might have.

Salience The salience dimension of proximity/borders is concerned with the importance or value of territory along or behind a border. The salience index was developed in much the same fashion as the index for opportunity for interaction. After reviewing the various coverages, the salience or importance of a border area was determined by places of population concentration, airfields, and selected cultural features located within a 50,000 meter buffer of the region's borders.[14] The distribution of these features is presented in *Overhead #5.* One rule that was used across methodologies, was that a capital city was automatically coded with the highest value found in any of the units of analysis. The results for the Starr and Bain analysis employing hexagons (and density of features) is shown in *Overhead #6.*

The revised methdological approach to salience is described by Thomas: "The willingness for interaction component of the study provided more of a challenge in using a vector approach because the hexagons were used to 'count' the number of cultural features, number of population centers, and number of airports within each one. Using the POINTDISTANCE command in combination with a FREQUENCY command allowed each feature to be given a value based on the number of other features that were within 4 kilometers. These could then be mapped based on the value, showing where clusters arose" (August 1996 Technical Report). The results of these revised analyses are shown in *Overhead #7.* This overhead displays the clustering of point coverages indicating the importance of an area, with graphics representing the numbers of points that overlap within four kilometer ranges.[15] While reducing the time and capacity requirements for analysis, the non-hexagon based datasets/methods also produce more graphically pleasing and interpretable results.

Again, *Overheads #6 and* #7 are important in the way they demonstrate how borders may differ in their importance— in terms of where people live, where the capital city is located, where significant elements of the transportation, military, or economic systems are situated. Portions of borders where more of these items are located, (here within a 50,000 meter buffer of the border), could be seen as more important or salient (in *Overheads #6 and #7* the areas in red or orange) than segments without population centers, or economic, military or transportation facilities. And, again, each separate arc (for example, Israel's border with Syria) could be categorized as one with low, medium, or high salience. As with opportunity for interaction, this representation of the salience of borders permits us to differentiate whole borders (or arcs), to differentiate portions of long borders, and to make sense as to why some borders might be seen as more important than others; why changes or events across some borders might generate more uncertainty than occurrences across other borders.

"VITAL BORDERS" AND THE STUDY OF INTERNATIONAL RELATIONS

Constructing Vital Borders

The use of a GIS dataset, then, permits a new mechanism for operationalizing a state's borders. We can now go beyond simply noting the existence of a border, or its length, or noting its "type" (eg., contiguous land or across-water borders). As noted above, we have used the GIS to create new data. Through the indexes generated, we can attach values (nominal, ordinal or interval) to a single dyadic border (or arc), or border segment. These values will indicate the ease of interaction provided by that border, and/or the importance of any particular border or border segment. These two dimensions can be used separately or combined. Recall that Most and Starr (1989) argue that opportunity and willingness are jointly necessary conditions for certain types of behavior, and that they are related to each other in complex ways (see also Cioffi-Revilla and Starr, 1995). A border with high values on both could be considered a "vital border," (as presented in *Overhead #8).* Again, the indicators of vital borders are new data, which can be used to re-investigate previously studied questions or address new ones, as discussed below.[16]

Overhead #8 indicates that four categories have been used in combining opportunity for interaction and salience.[17] Given that both opportunity for interaction and salience were presented as 4-point scales, their joint combined value can run from 2-8. For a border to be considered "vital" it must have a joint value of 7 or 8~ demanding a value of either 3 or 4 on each dimension; represented as red areas on *Overhead #8.* Dark green areas represent border segments which are the "least vital"— borders difficult to cross, and holding little of specific value. Vital borders represent areas that are both highly permeable— easy to cross— and also encompass population centers and/or features of economic, political or social importance. As discussed in Starr and Bain (1995), one possibly important comparison would be to see how closely vital borders correspond with Boulding's (1962) idea of a "critical boundary."[18]

One basic point raised in Most and Starr (1989) was that researchers needed to be much clearer as to the broader concepts which were really under investigation, so that their models and the resulting research designs could be more logically and fully specified. Perhaps "borders" can be used in some research for reasons that are innate to "borderness"-- that they separate entities from one another. However, as discussed above, most uses of borders involve their representation of proximity— that is, entities are close to one another, important to one another, and have an enhanced ability to interact with one another. But, does the existence of a border actually respresent these notions? Borders that are difficult to traverse, either commercially or militarily may not fit this idea of proximity. Borders which are "buffered" by empty and meaningless spaces may not fit this idea of proximity. The concept of a vital border— with its two subcomponents— specifies more completely and precisely how a border might represent "proximity."

Revisiting IR Hypotheses with Vital Borders

A wide array of research questions based on the assumption that borders indicate proximity, salience, and ease of interaction may be addressed by a vital borders dataset generated from the ARC/INFO GIS.

Which types of borders are most or least related to spatial diffusion? As noted, the Most and Starr analyses of the diffusion of conflict (e.g. 1980) were based on the notion that borders represented the qualities of salience and ease of interaction. They investigated whether states which were subjected to the "treatment" of having a Warring Border Nation (WBN) were more likely to become involved in conflict than those without such a treatment. In later analyses, Siverson and Starr (1991) added the "treatment" of having a Warring Alliance Partner (WAP). One finding of Siverson and Starr (1991, 54-55) is that the relationship between joing an ongoing war and being subjected to WBNs and WAPs is one of "loose necessity." Many states have treatments, but do not join wars. In fact, having only one treatment (only one WBN and/or WAP) appeared to have almost no effect on the behavior of states. One research project using the new Vital Border dataset would be to investigate the nature of the borders that separate the state from its WBN. If the border is a vital border, does it increase the probability of the diffusion of war/conflict.[19] That is, both sets of studies were concerned with "treatments." A new null hypothesis could be that any WBN treatment enhances the probability of war diffusion. More fully specified hypotheses would propose that vital border WBNs have a greater probability of enhancing diffusion; (or that a border needs to score high on either salience or opportunity for interaction). Is it simply "borderness" in some vague sense, or these more specific qualities that are involved?

The Lemke studies (1995, 1996) noted earlier raise the same question. As with Most and Starr, Lemke is concerned with the key question of identifying "relevant dyads." Indeed, he goes beyond this to try to identify "relevant neighborhoods." Using Bueno de Mesquita's (1981) operationalization of Boulding's "loss-of-strength gradient," Lemke is concerned with the distance over which military forces can move in specific periods of time, and how this relates to the propensity for wars or MIDs. Interestingly, Lemke (1996) specifically notes his concern with paved roads and railroads in attempting to estimate the loss-of-strength gradient (and thus, the relevant dyads/neighborhoods) for African states. Lemke has also moved beyond simply assuming that borders indicate proximity and thus the ability to fight. Using the opportunity for interaction index, the question can be specified even more closely. Another research project could involve the comparison of Lemke's findings to those based on GIS generated border data on opportunity for interaction.

Is it the nature of the border rather than numbers of borders that affect conflict behavior? The discussion of borders and diffusion indirectly raises this question as well. Boulding (1962) not only introduced the loss-of-strength gradient, but the concept of critical boundaries as well. Both were related to Boulding's concern with the viability of states in regard to neighbors. One suggestive analysis in Starr and Bain (1995) was that the GIS-generated maps of salience and opportunity for interaction, indicated that in 1967 Israel had changed its legal borders with Jordan and Syria to match what could be considered to be its critical boundaries. What is the relationship between vital borders and critical boundaries? Are attempts to match the two behind the events listed in the MIDs dataset? causes of war in general? causes of wars over territory in particular? Further refinement of the procedures used (particularly the size of the buffers employed) for generating vital borders are clearly needed, as is an independent operationalization for critical boundary. But even setting aside the question of critical boundaries— do states (especially those with large numbers of borders) demonstrate a higher incidence of conflict along vital borders? along salient borders? along borders with greatest ease of movement?

This discussion generates several related questions, For example: What sorts of borders can be found between states in enduring rivalries? What is the nature of the territory over which conflicts arise? Goertz and Diehl (1992) and Holsti (1991) both focus on territory *per se* as a cause of war; as both the issue over which war breaks out, and as a factor which increases the stakes of a war. These analyses provide us with a very important null hypothesis: it is territory— any territory— which creates an opportunity for conflict, which serves as the issue for war, and which makes the stakes worth fighting over. In contrast, the research question generated here is whether or not conflicts, MIDs, wars over territory, are more likely to involve territory that includes or cuts across vital borders.[20]

By introducing issues and stakes I have also returned to questions of willingness and uncertainty, and the relationship between interaction opportunity and utility calculations discussed at length in Siverson and Starr (1991, chapter 5). That discussion, as well as any based on models of expected utility, must take into account the possibility that specific pieces of homeland territory might be seen as more important or less important; that some borders might be seen as more important than others. If so, then the decisions to escalate conflict, even to the point of organized armed violence, must address such differences. Datasets of the sort described here can permit the testing of the impact of such differences.

CONCLUSION

In an investigation of the nature and impact of borders, Starr and Most (1976) conceptualized borders in terms of both opportunity and willingness. One key aspect of borders is that they affect the interaction opportunities of states, constraining or expanding the possibilities of interaction that are available to states. States that share borders will tend to have a greater ease of interaction with one another. Secondly, borders also have an impact on the willingness of decision makers to choose certain policy options, in that they act as indicators of areas of great importance or salience.

The ARC/INFO GIS permits us to operationalize and investigate these two dimensions-opportunity as ease of interaction, and willingness as salience/importance. Using data available in the different data layers found in ARC/INFO's Digital Chart of the World, we have constructed indexes of both ease of interaction and of salience. These indexes aggregate values generated from ARC/INFO. They can be used to characterize any border (or arc) or border segment on the globe. The use of a GIS dataset, then, permits a new mechanism for operationalizing a state's borders. We can now go beyond simply noting the existence of a border, or its length. Through the indexes generated, we can attach values to the ease of interaction a border or border segment provides, and/or the importance of any particular border or border segment. These two dimensions can be used separately or combined. A border with high values on both could be considered a "vital border." The GIS generated indexes permit us to tap both dimensions, and to use them singly or combined given the research question under consideration.

NOTES

1. I would like to acknowledge the support for this project provided by the University of South Carolina Humanities and Social Sciences Computing Lab (David J. Cowen, Director), and the Walker Institute of International Studies (Donald J. Puchala, Director). Support has also been provided through a 1996 University of South Carolina Research and Productive Scholarship Grant. In addition, special thanks must be given to Will Bain, Deb Thomas and Richard Deal for their invaluable research assistance in translating my vague ideas into actual GIS output. Thanks to Dave Cowen for comments on earlier papers. I also want to thank Lynn Shirley and Geoffrey Ehler of the Computing Lab for their technical advice.

2. Perhaps one arbitrary signpost would be that Starr and Most's, "The Substance and Study of Border in International Relations Research" was published in 1976.

3. Note that this conceptualization of interaction opportunity is also usefully complementary to Choucri and North's (1975) notion of lateral pressure "intersections."

4. Much of the material here has been taken from Starr and Bain (1995).

5. For just a sample of GIS overviews, see the edited volumes of Maguire, et. al. (1991), or Peuquet and Marble (1990a). See also widely used textbooks such as Aronoff (1989).

6. This section is based on material provided by ESRI (1992), *ARC/INFO: GIS Today and Tomorrow.* For a briefer introduction to ARC/INFO, see also Peuquet and Marble (1990b).

7. In addition to the large scale database, the DCW contains a utility directory, referencing such material as small scale reference maps, data quality information, and DCW technical information. The various utilities are useful in providing base maps for cartographic output and verifying data extraction from the CD's.

8. Without going into detail, it should be noted that there are indeed time and memory considerations in planning the extraction and combination of data. Extracting large quantities of data tiles is best accomplished by identifying the individual coverages for specific data tiles desired by the user and inputting their designators into an Arc Macro Language (AML) file. Some coverages take longer to extract than others. Typically these coverages are the net and polygon coverages which are characterized by more complex data structures than line and point coverages; (the Hypsography and Drainage Network coverages are typically the largest). Furthermore, in most cases, a larger number of data tiles requires a longer period of time to extract than a smaller number of tiles. When dealing with large spatial areas such as regions or continents, the necessary time needed to extract data can become extremely long.

9. As actually called for as long ago as 1962 by Wesley!

10. Again, it is interesting to note that Wesley (1962) suggests that scholars use cross border roads to operationalize geographic opportunity, and that Lemke (1996) uses roads and railroads in a similar manner.

11. NOTE: The panel presentation of this paper involved the presentation of multicolor overheads. At this time these overheads have not been redesigned to be included in the hardcopy version of the paper in black and white representations. Thus, with apologies, the paper will only include references to *Overhead #___* presentations.

12. In her technical report of August 1996, Deb Thomas discusses the change in methodology, and presents the procedures for determining the opportunity for interaction:

> Originally a hexagon layer was utilized as the basis for the analysis. Several reasons were cited for this, including the fact that hexagons are an efficient way to represent space, they are more visually appealing than squares, the relational qualities of the hexagon are conducive to some GIS applications, and that a long tradition of using hexagons exists in the field of international studies. Without a doubt, this is an interesting application of hexagons within GIS. In terms of the goals of the project, however, the use of hexagons did not appear necessary.
>
> While it is true that many consider hexagons more visually appealing than squares and that they are an efficient way to represent space, this does not truly provide a basis for performing operations using hexagons. In addition, the original methodology did not

include modeling. The vector data were simply superimposed onto a hexagon surface. Through this process, each hexagon was assigned a value determining either its opportunity for interaction or the willingness for interaction. Consequently, using the vector data directly appeared to be a better option. In this way, the artificial boundaries produced by using hexagons and the generalization that resulted were no longer issues. Perhaps the best argument for using hexagons for this application is the tradition of using them in international relations, but this in and of itself was not a strong enough reason to continue to use the hexagon.

The opportunity for interaction of the study used roads, railroads, and hypsography coverages from the Digital Chart of the World. The steps for determining the opportunity for interaction are described below:

(1) The road layers (rdmulti and rdprim) were created by using the RESELECT command two times on the rdline layer. One step reselected rdlntype = 1 to create a coverage of the multi-lane divided highways. The second step reselected rdlntype = 2 to create a coverage of the primary and secondary roads. Both of these were then built.

(2) The railroad coverage (rail) was created in a similar fashion. Using the RESELECT command on the rrline coverage to reselect rrlntype ne 3 and rrlntype ne 8 to create a coverage the eliminated light duty railroads and railroad connectors. This coverage was then built.

(3) The values for slopes were generated using a triangulated irregular network (TIN) CREATETIN was performed on the hynet coverage. From this TIN, an Arc/Info coverage was created using the TINARC command producing hynet-tin which had slopes in degrees in it.

(4) Features from these coverages were isolated in 10,000 meter buffers around the Israeli border by using the BUFFER, CLIP, and ERASE commands.

(5) Within each of the buffered coverages an item was added. So, in the rdmul coverage an item called value was added. Polygons that fell within the buffer were calculated to be 1. In the rdpri coverage, the item was called value2 and calculated to be 1 in the same way. In the rrpri coverage, the item was called value3 and calculated to be 1. In all three of the coverages, the value was calculated to be 0 for any polygon not falling within the 10,000 meters. For the slope coverage (elevat2) an item called value4 was added. This was calculated to be 1 if the slope was 0-5 degrees, 2 if the slope was 5-20 degrees, and 3 if it was greater than 20.

(6) After reducing the size of the dataset, the coverages were built and then combined in a series of overlays.

(7) Once the final overlay was complete, a map of the opportunity for interaction was produced in ArcPlot using an AML. The AML describes the combinations that were used to determine the four categories of opportunity for interaction.

13. The Opportunity for Interaction/Ease of Interaction index was developed as follows:

4= presence of a road and the presence of railroad, and low slope

3= a road or a railroad, and low slope
3= a road and a railroad, and medium slope
3= no road, no railroad, and low slope

2= a road or a railroad, and medium slope
2= a road and a railroad, and high slope
2= a road or a railroad, and high slope

1= no road, no railroad, and medium slope
1= no road, no railroad, and high slope

14. Areas of urban concentration including urbanized areas and capital cities were extracted from the Populated Place Layer, Layer 2 (PPPOLY and PPPOINT). From Layer 13, the Aeronautical Layer, active civil and military airports were identified (AEPOINT). The Cultural Landmark Layer (Layer 14) provides a catalogue of items that would indicate the importance of an area, including: military camps, forts, oil wells and refineries, power plants, water tanks, etc.

15. Richard Deal, in his October 1996 Technical Report, describes how salience was represented:

> The salience coverage was constructed by first combining all the point coverages (airports, populated places and cultural features) into one coverage. To measure where clusters of points were the pointdistance command was used. The specified search distance was 4000 meters, so as to be approximately equal to the size of the hexagons in the previous portion of the work. The next step was to use the frequency command on the info file that was generated by pointdistance. The info file created by this command was added to the salience coverage using joinitem.
>
> These steps resulted in a coverage, salience2, which has all the points and an item frequency, which shows the salience of that point. The frequency ranges form 1 to 6. Jerusalem was adjusted to have a value of 6 so it is tied for the highest value on the coverage. An ami called salami creates the salience map.

16. Such newly created data can be removed from the GIS for further analyses with variables not included in the GIS (such as, for example, location of ethnic groups). However, one positive feature of the GIS is the ability to add data newly generated from the GIS (such as opportunity for interaction or vital borders) into analyses using other data in the GIS, or to input new variables (such as ethnic data) into the GIS for analysis.

17. Deal's October 1996 Technical Report provides the following discussion of how the index of vital borders was created:

> The new salience coverage is only used as an intermediate step in creating the vital borders coverage called inter_sal, because it has both interaction and salience. Salience and interact were joined using the intersect command. A new item called sal was added in order to assign frequency a value from one to four. Frequency values of one and two remained the same, three and four became three and values over five were assigned a value of four. With this reassignment, areas have a value for salience and interact of between one and four so when they are added together, all areas have a value of between two and eight. This was done in a new item called vital. Two amis were created to plot out the vital border maps; they are vital2.aml and vital3.aml.

18. Boulding (1962, 265) notes:

> The legal boundary of a nation, however, is not always its most significant boundary. We need to develop a concept of a critical boundary, which may be the same as the legal boundary but which may lie either inside it or outside it...The penetration of an alien organization inside this critical boundary will produce grave disorganization... War, therefore is only useful as a defense of the national organism if it is carried on outside the critical boundary (emphasis in original).

19. The Most and Starr studies investigated the positive spatial diffusion question of the onset of violent conflict— where and under what conditions; the Siverson and Starr studies looked at the spread of ongoing wars. While both may be seen as forms of diffusion, it should be clear that they are different types of diffusion, and are not the same questions.

20. Wallensteen and Sollenberg (1996) provide a compilation of armed conflict after the Cold War— from 1989 to 1995. They also code each conflict for the "incompatibility" or issue. The majority of these armed conflicts note territory as the incompatibility.

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1. List of Data Layers in the ARC/INFO Digital Chart of the World

- Political and Oceans
- Railroads
- Utilities
- Hypsography
- Drainage Supplemental
- Physiography
- Cultural Landmark
- Vegetation
- Data Quality
- Populated Place
- Roads
- Drainage
- Hypsography Supplemental
- Ocean Features
- Aeronautical
- Transportation Structure
- Land Cover