Comprehensive Fault Database and Interpretive Fault Map of Oklahoma

Stephen Marsh and Austin Holland
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Oklahoma Geological Survey
The University of Oklahoma
100 East Boyd Street Suite N131
Norman, OK 73019

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Stephen Marsh
Email: stephen.j.marsh@ou.edu

Austin Holland
Email: austin.holland@ou.edu

Summary

The Oklahoma Fault Database (OKFault) is the most comprehensive compilation of mapped faults within Oklahoma. This effort captures faults from published literature and the necessary metadata, so these faults can be referenced in the future. Both surface and subsurface faults are being documented within the same database framework, however they are only represented on a 2-dimensional plane and do not have 3-dimensional projection. The database framework is based in modern open-source GIS platforms. This is a large and ongoing effort, constructed for newly identified resources to be incorporated and updated into the existing database. Initially, there was no effort to prevent duplicate fault characterizations from multiple sources, this was done intentionally to allow comparison between different author representations of the same fault. Therefore, the second part of this effort is to build an interpreted fault map which provides a single representation for multiple mapped versions of the same fault and evaluate faults based on their associated metadata. The goal is to provide a single fault map that represents the geologic complexity within Oklahoma. Ultimately, there will be two separate products: a comprehensive fault map, and an interpreted fault map. A preliminary interpreted fault map is available, Holland (2015). OKFault allows users to easily access and use any information about any fault and those faults used to help constrain the interpreted faults. This database is a unique and valuable resource that will be publicly available to all types of end-users and collaborators.

Introduction

There are many faults within Oklahoma, and many are still unknown. The Oklahoma Fault Database captures all faults within Oklahoma that are available in published literature and provide a representation for each known or suspected fault. Each fault that exists in the database has metadata associated with it. The metadata allows us to track important information unique to each individual feature. Metadata includes: quality of the mapped fault, which is based on a confidence rating, the formation it is mapped in, the dip-direction of the fault, and a reference to the original publication from which the geo-referenced feature was mapped. Furthermore, some faults have other metadata types associated with it when the information is available in the publication. This information may include the name of the fault, whether or not it is a surface fault, and what type of fault, i.e. Strike-slip.

While OKFault shows many of the known faults in Oklahoma, it is incomplete. There are still faults unknown to the scientific community, which continue to be discovered as new research is published. Moreover, many known faults have yet to be entered into the database due to the enormous volume of publications available. Therefore, it is important we release this resource to the public with the information that has been cataloged, which will be useful for future research. However, the database was created with the intention that it would be further enhanced.

There are two types of maps that are included in OKFault; one is comprehensive and the other is interpretive. A Preliminary Interpretive Fault Map has already been created (Holland, 2015). The Comprehensive Map includes all faults published and makes no effort to eliminate multiple representations of the same fault. The Interpretive Map is an interpretation of the Comprehensive Map and eliminates duplicate representations in order to create a map with a single representation of each fault.

The OKFault maps are built using QGIS open-source software, and will be publicly available. Anybody can access the database and find information about a particular fault. It is designed to allow users the freedom to access any fault within the database that is relevant to their needs, reference it and obtain a digital representation of the fault. Examples of publications benefiting from this effort include a determination of optimally oriented faults within Oklahoma (Darold and Holland, 2015).

There is no resource to date which attempts to accomplish the same goal. This project is unique in that it is an attempt to capture the known fault structure of the entire state of Oklahoma. Overall, the OKFault database carries a vast host of fault data with the capability of further expansion. With this information available, a database such as this serves not only to provide a repository for Oklahoma fault data, but it also aids in the creation of a comprehensive and interpretive fault map for the continued benefit of all users.

Methods

Most of the faults in the database only existed in published literature before this project, and in order to create the database, this effort required all published faults to be manually digitized. By taking a scanned copy of a structure map, the fault is geo-referenced using QGIS software and fault segments are then digitized onto the map to create a digital copy of the feature. Once the feature is created, the metadata (Table 1) is edited for that particular fault and any further information from the publication is added.

The name refers to the scientific community's name for the fault. If the original paper publishes a structure map that includes the Meers Fault or Choctaw Fault or some other named fault, then the fault is geo-referenced and traced to include the name given by the author in the metadata.

Quality of representation for the faults is another important aspect to take into consideration. Some faults found in publication are surface faults and are known to exist at that location, while other faults are subsurface faults and the location can only be inferred. Thus the confidence rating of this fault is not as high in areas where they are inferred. A letter grade is assigned to each fault to differentiate the quality; this scale includes "A, B, C, and D". The grade of "A" is for faults who have an excellent representation, meaning that the fault was mapped using 3-D seismic techniques or mapped at the surface. Only the publications that have mapped features with a high confidence level are awarded a grade of "A". The next rank down is a quality of "B". This refers to a good quality mapped using 2-D seismic methods with well data or it is a concealed surface feature. The "C" quality is a fair rating, determined when the fault is inferred using dense well control but cannot be confidently represented. The final quality rating is a grade of "D" which inferred mapping using sparse well control. A grade of "D" is used for a very low confidence and poor quality representation of known features.

Table 1 – Metadata fields and their descriptions and classification used in OKFault

Metadata Classification	Description
Name	This is an identifying word or phrase if the fault has been given a name.
Quality	A confidence rating of the mapped feature. The rating of “A” being most confident followed by “B”, “C”, and finally the rating of “D” being the least confident.
Formtop	If a structure map indicates a particular formation top, such as the “Hunton”, that formation name is provided here. Knowing this can help determine the depth of a fault or differentiate between faults that have the same horizontal location but differing depths.
Formbottom	If a structure map indicates a particular formation base, such as the “Arbuckle”, that formation name is provided here.
Dip	This tells the user which direction a fault is dipping. There are only eight distinct directions provided. North, South, East, West, Northwest, Northeast, Southwest, and Southeast. This can be important to know for any sort of structural or seismic analysis.
Shortref	This is a short reference to the publication used in mapping the feature. It only includes the lead author's last name with the year of publication. If there are multiple authors “et al.” is included after the name. Ex. Northcutt et. al. (1995)
Reference	This is the full reference to the publication. It includes every author contributing to the publication, along with the year of publication, title, and the publisher. Ex. Northcutt, R.A., Campbell, J.A., 1995, Geologic Provinces of Oklahoma, Oklahoma Geological Survey Shale Shaker, pg. 99-103.
Slipsense	The slip sense of a fault indicates what type of fault it is, a normal fault, thrust fault, or strike-slip.
Surface	If the fault is known to be a surface feature, the letter “t” is used to denote that that fault is a “true” surface feature. If the space is left blank, the feature is not known to be a surface feature.

The Comprehensive Fault map was created by digitizing every fault found in a publication. This means if a fault has been mapped and digitized already, we still included other representations of the fault, from different authors into the map. This is done for a better image of where people believe each fault lies. By comparing traces of the same fault from different authors and taking into account the weighting quality, a single representation of that fault can be established. In addition, including representations from different published sources allows for a quantification of fault location uncertainties either for a single fault system or more generally for subsurface faults in published literature. The references for all faults included in the OKFault database at the time of publication are included in the references for this report.

Using the method described above we can go through every fault trace on the Comprehensive Map and determine if it has other representations and create a single representative fault. Once the entirety of the Comprehensive Map is interpreted and includes only single fault traces for each individual fault, these traces are then compiled to create the Interpretive Fault Map.

Discussion

There are many faults represented in OKFault, but there are many more to capture and will continue to be updated. One of the goals of this project is to eventually create a complete picture of Oklahoma's fault structure. Unfortunately, there are regions in Oklahoma, particularly counties in northwestern Oklahoma, which have fewer fault representations than the region of southeastern Oklahoma. While the goal is to populate those regions with fault information, it has not been possible at this point due to several reasons. First, either fewer faults truly exist in northwest Oklahoma or, in the more likely case, relatively little mapping has been completed in that region to determine fault locations. Another reason would be that many of the publications containing such information may not be available to us at this time.

Another important goal for the OKFault database is to provide information about each fault. This database will be publicly available to any stakeholder and each user may acquire different information about any fault. In order to accommodate this need, each fault is provided with as much information as is available in the original publication. This includes information such as the name of the fault, quality rating, formation top, formation bottom, dip-direction, short reference, long reference, slip-sense, and surface.

The metadata is an extremely important component of the database. Both maps, the comprehensive and interpretive, do not have a three dimensional visual component to understand the subsurface extent of each feature. The metadata allows the user to gain a better understanding of the geographic location of the fault as well as the quality. If the user finds the provided information inadequate, the metadata also includes a reference to the original publication so the user may obtain an even greater understanding of that particular fault through the publication from which it is referenced.

Most publications focus on relatively small regions for the study done. These can range from an area less than a single township to a region that includes multiple counties. As a result, studies may be very localized and people can have a hard time tracking down publications which discuss a particular region of interest. This is why both the Comprehensive Map and Interpretive Map are important and unique resources. They are convenient, all-inclusive resources giving users access to obtain information about the known fault structure anywhere in Oklahoma.

As mentioned before, there are two separate, but related maps in the database. There is a

Comprehensive Fault Map and an Interpretive Fault Map. The Comprehensive Fault Map is designed to show every feature digitized with the associated metadata. This allows users to look at a certain region and get an idea of how multiple publications have different representations of, possibly, the same feature. Another reason to make the Comprehensive Map public is to allow users to make their own interpretation of the fault structure of Oklahoma. While the database does provide an Interpretive Fault Map, there is undoubtedly multiple ways to interpret the Comprehensive Map. By including it, we can allow the user to find meaning through their own analysis and studies of Oklahoma faults.

The Interpretive Fault Map is just one possible interpretation of Oklahoma's fault structure. The Comprehensive Map includes every variation of a mapped fault while the Interpretive Map attempts to create one representation of what is available in the Comprehensive Map. This map is publicly available to allow users to obtain information without having to sift through the complexity of the Comprehensive Map. It is also valuable to non-science users who are interested in seeing how geologically complex the state of Oklahoma is and, potentially, the origin of so many new earthquakes.

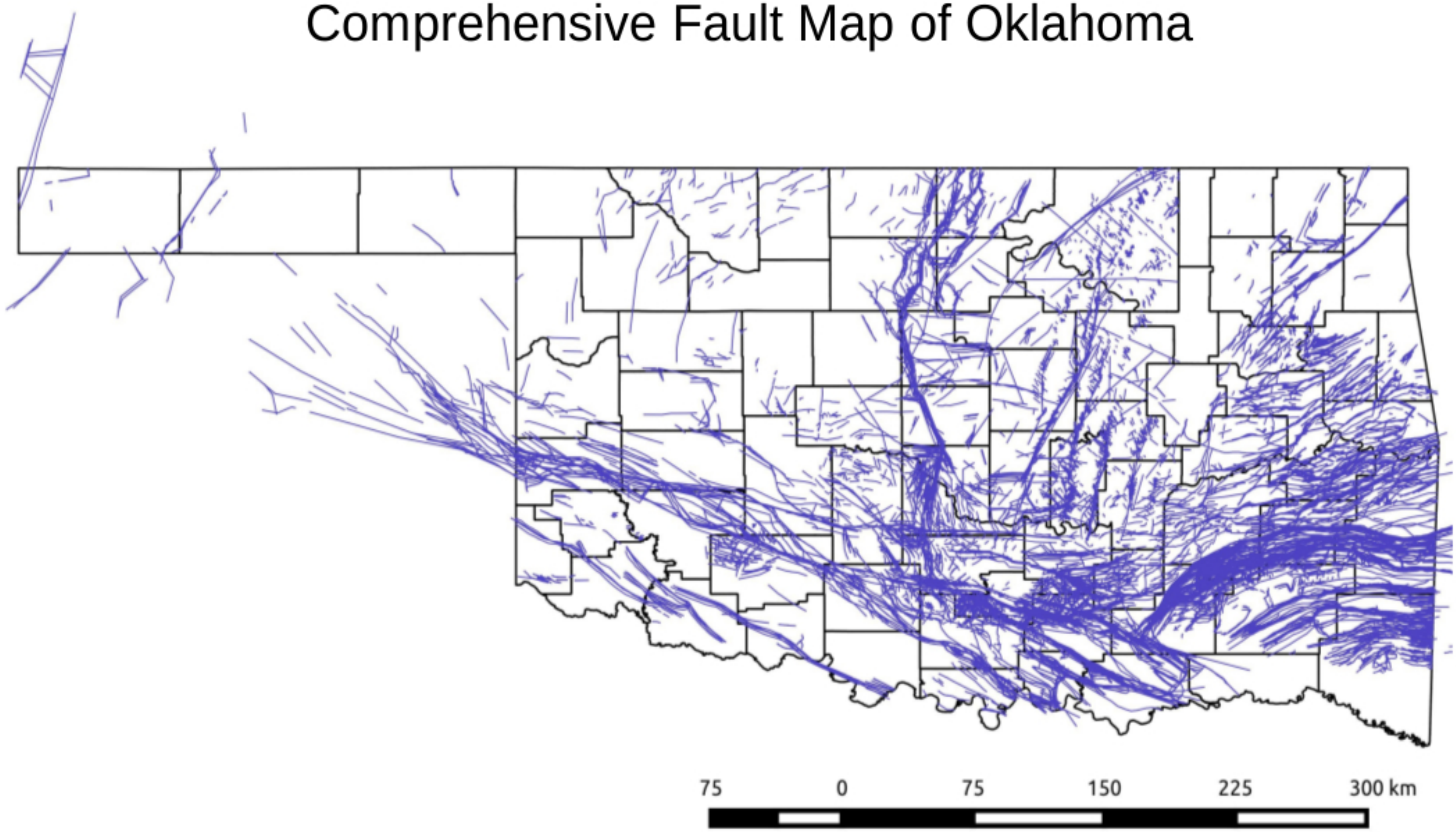
The recent trend of new earthquakes in Oklahoma can be better understood when the fault structure of the state is known. There either has to be an existing fault or the creation of a new fault in order for an earthquake to occur. Whether or not the earthquake is naturally occurring or induced, there must be a fault from which the earthquake originated. Both the Comprehensive and Interpretive Fault maps can be useful in determining and understanding earthquake hazard assessments, fault orientations, and focal mechanisms (Darold and Holland, 2015; Holland, 2014).

Conclusion

The faults that are mapped in the OKFault database should be interpreted as a general representation and not be interpreted as the true location and information of the fault. Each fault was mapped using different methods from different time periods ranging from as early as 1910 to as recent as 2015 and using different methods. The database is the best representation of the mapped faults in Oklahoma, but should not be considered complete and no guarantee is made about the accuracy of included information. At the time of this document the comprehensive fault database contained 19,350 unique features from 169 different references. Instead, the faults should be seen as a resource to supplement existing studies in the geology of Oklahoma. There are regions that have sparse fault coverage on these maps compared to others, and this is due to a lack of resources. However, newly discovered faults can be added to the database as they are found to continuously improve our understanding of the state and thus fill some of those sparse regions.

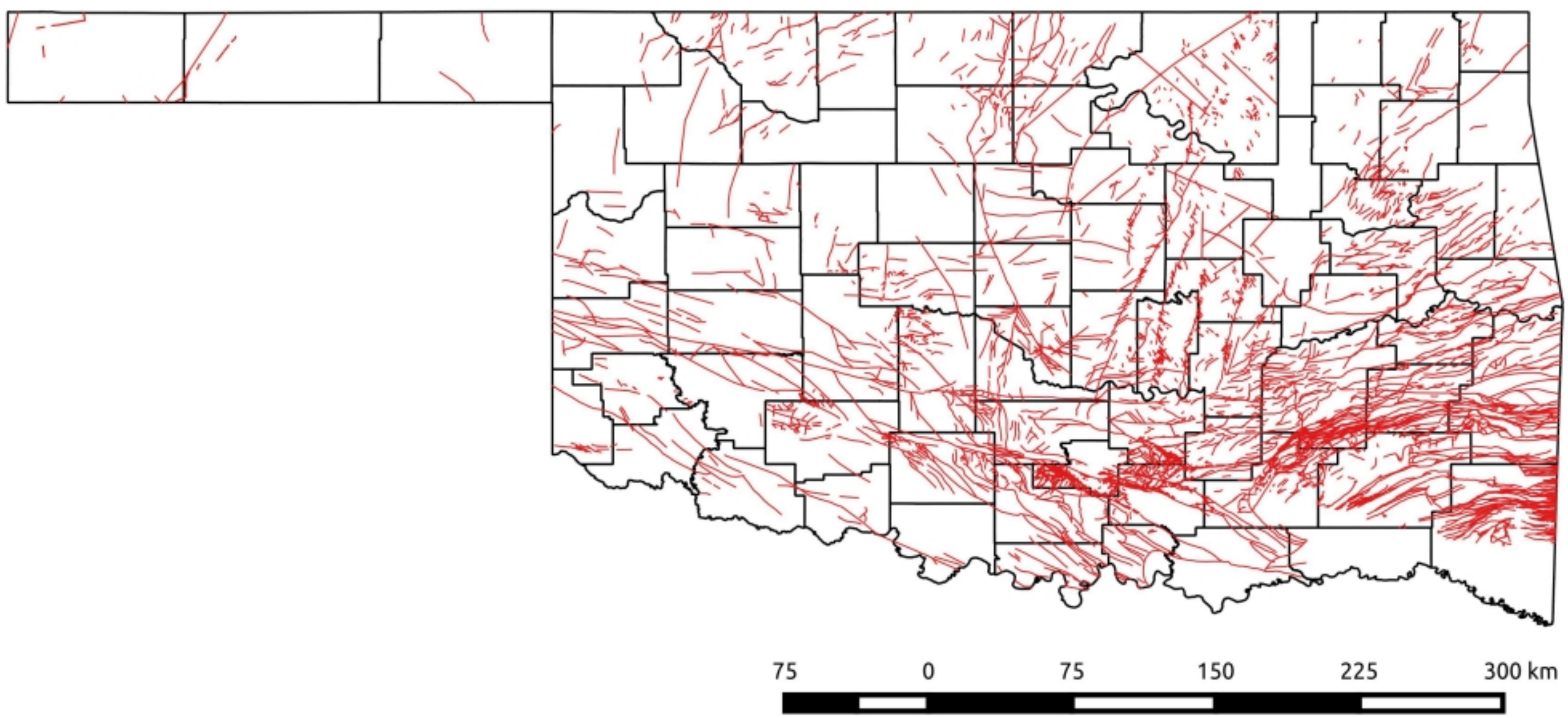
Ultimately, this database has been and will continue to be useful for studying the ongoing seismicity occurring within Oklahoma. Understanding the fault structure of the state may help expand our understanding of how and why earthquakes are occurring in Oklahoma. These maps may help to facilitate research in these keys areas. With the faults that are known and shown here, we can correlate those with actively seismic regions. In doing this we can help further our knowledge and understanding of seismicity.

Comprehensive Fault Map of Oklahoma



This figure is also available as a separate plate in addition to this publication.

Interpretive Fault Map of Oklahoma



This figure is also available as a separate plate in addition to this publication.

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