China Active Faults Database (CAFD) and its Web System

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Abstract. Active faults ~~are~~ serve as potential sources of~~potential~~ destructive earthquakes ~~sources and also the most serious strips of earthquake disasters in the future~~. Studies and investigations of active faults are necessary for earthquake ~~hazard~~ disaster ~~reduction~~prevention. This study presents a nation-scale database of the active faults ~~for~~ in China and its adjacent regions in tandem with an associated web-based query system. This database is an updated version of the active faults data included in the "Seismotectonic Map of China and its Adjacent Regions (1:4 000 000)," which is one of the four essential maps of the mandatory Chinese standard GB/T 18306-2015 Seismic Ground Motion Parameter Zonation Maps of China. The data update and integration ~~are based~~stem from ~~on~~ regional-scale studies and surveys conducted over the past two decades~~on the latest 20-year region-scale active faults performed in the latest 20 years~~ ~~survey data~~ (at~~1:250 000 – 1:50 000~~ reference scales from 1:250,000 to 1:50,000). The information amasse~~Those~~ ~~The data collected in~~d from these regional-scale studies and surveys encompasses ~~include~~ geophysical probing, drill logging, measurement of offset-landform~~ measuring~~, ~~and~~ sample dating, as well as geometric and kinematic parameters of exposed and blind faults, paleo-earthquake sequences, and recurrence intervals~~, and~~. These data have been acquired~~obtained~~ and analyzed utilizing a uniform~~using the same~~ technical standard framework and reviewed by expert panels in ~~the~~both field and laboratory settings. Our system hosts ~~T~~th~~e~~is nation-scale database accessible through a~~in our system~~ ~~can be interrogated using a~~ Web Geographic Information System (GIS) application, ~~which provides~~enabling browsing, ~~in~~quiring, ~~analyzing,~~ and downloading ~~functions on~~functionalities via a web browser. The~~The~~ system we built also publishes the Open Geospatial Consortium (OGC) Web Feature Service and OGC Web Map Service of active fault data. Users can incorporate map layers and obtain fault data in OGC-compliant GIS software for further analysis through these services~~Users can add map layers and download fault data in the OGC-compliant GIS software for further analyses via these services~~. The Chinese government, research institutions, and companies have widely used the active faults data from the previous versions of the Database. The database is available at

https://doi.org/10.12031/activefault.china.400.2023.db (Xu, 2023) and via the Web System (CEFIS (V2), 2023; CAFD WFS). ~~It is downloadable through diverse platforms and clients as introduced in Sections 4.3.2 and 4.4.~~

1 Introduction

Earthquake is one of the most dangerous natural disasters in the world. A ~~close~~ causative relationship exists between large or great earthquakes and ~~the spatial distribution of an~~ active faults. ~~In general~~Typically, ~~an~~ earthquakes ~~of~~ with magnitude (M) ≥ 7.0 often ~~occurs on~~originate from Holocene or Late Pleistocene active faults or their epicentral zone overlaps such faults~~overlaps with them~~. ~~In statistics，~~ Statistical analyses reveal that nearly~~almost~~ all ~~M≥ 8.0~~ earthquakes with M≥ 8.0 and ~~most~~ the majority of those ranging from~~M=~~ 7.0 to~~–~~ 7.9 ~~earthquakes~~ in China ~~have been associated with~~are linked to rupture ~~parts~~ segments of the ~~main~~ primary boundary faults surrounding~~around~~ the Tibetan Plateau block in western China and the Ordos block in Central and East China (Xu and Deng, 1996; Deng et al., 2003; Zhang et al., 2003; Xu et al., 2016a). ~~Furthermore~~Moreover, ~~more than~~over 70 co-seismic surface rupture zones ~~generated by the~~resulting from ~~great~~ large earthquakes ~~are~~ align spatially ~~coincident~~ with ~~the~~ known active faults (Xu and Deng, 1996; Zhang et al., 2003; Xu et al., 2017). ~~Therefore~~Hence, ~~determining~~ the identification of active faults, delineation of their ~~the geometries~~ traces and locations~~, of the active faults and~~determination of their slip rates, and subsequent compilation of ~~then constructing~~ a comprehensive corresponding database ~~of the active faults is essential for preventing~~are imperative for averting and mitigating the social and economic ~~losses caused by destructive~~ramifications of earthquakes~~, and protecting~~ as well as safegarding lives and property (Xu et al., 2002, 2006; Tian et al., 2006). This article introduces a ~~public~~ publicly accessible, national-scale ~~active faults~~ database ~~of~~detailing fault traces, latest active ages, and motion modes of active faults in China.

~~Some~~ Several countries have ~~constructed~~ compiled comprehensive active faults databases ~~in~~ over the past ~~twenty years~~two decades (Haller et al., 2004; Basili et al., 2008, 2021; Yoshioka and Miyamoto, 2011; Ganas et al., 2013; Langridge et al., 2016; Emre et al., 2018, Maldonado et al., 2021; Williams et al., 2022), some of which are ~~publicly~~ available to the public. For ~~example~~instance, the National Institute of Geophysics and Volcanology of Italy published the Database of Individual Seismogenic Source (DISS) in the 2000s and the database of Active and Capable Faults in ITaly HAzard from CApable faults (ITHACA, 2024) project. The latest ~~version~~ iteration of DISS, ~~is~~version 3.3.0 (Valensise and Pantatosti, 2001; Basili et al., 2008, 2021~~).~~), ~~This latest database~~ includes ~200 faults. The U.S. Geological Survey established the first nationwide compilation of the U.S. Quaternary Faults and Folds Database in the early 2000s, ~~which contained~~containing ~2000 faults (Haller et al., 2004).

China is located in the convergence zone of the Indian, Eurasian, and Pacific Plates where many seismogenic active faults have developed, and becomes one of the countries with the most severe earthquake disasters at present and also in history. An active faults database of China is essential for ~~the~~ conducting in-depth ~~studies~~ analyses of regional crustal kinematic characteristics, intraplate earthquake features, and earthquake disaster mitigation ~~action programmes~~strategies. In the 2000s, ~~The~~ the China Earthquake Administration ~~built~~ developed a ~~1:4 000 000-scale~~1:4,000,000-scale active tectonic database (Qu,

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2008)~~ in the 2000s. ~~, ~~This~~which~~ database~~ was~~ based on~~derived from Deng's 1:4,000,000-scale active tectonic map and ~~included more than ~~encompassed over 800 active faults and 48 active folds (Deng et al., 2002, 2007). It summarized ~~researches ~~research on active faults carried out in China before 2002 AD. However, ~~many ~~numerous active faults ~~were not thoroughly~~remained inadequately identified or studied during ~~at ~~that ~~time~~period. In the following years, ~~several ~~subsequent field surveys ~~have been performed to investigate the ~~focused on investigating active neotectonic and seismic activities ~~of~~ within the Circum-Pacific and Himalayan-Mediterranean seismic zones in China. To determine the accurate ~~position ~~fault trace and age of the latest re-activation~~slip age~~ of active fault, which is of capable generating destructive earthquakes, a series of active fault surveys and mapping projects (Yang et al., 2018a, 2018b, 2020; Huang et al., 2021a, 2021b; Lei et al., 2008; Chai et al., 2011, Xu et al., 2015~~.~~) has been launched since 2007 in China. These projects consist of the following: 1) F~~f~~undamental maps and data collection for national earthquake hazard~~s~~ prevention, such as the 5th generation "Seismic ground motion parameters zonation map of China" (China mandatory standard GB/T 18306-2015~~); ~~). 2) Prospecting of active faults ~~prospecting ~~in urban regions and their earthquake risk assessments, such as "Urban active fault experimental prospecting" (2001–2003)(Pan et al., 2002; Wang et al., 2002) and "Seismo-active-fault prospecting technology system in China" (2004–2008) (Wang et al., 2004; Deng et al., 2007~~); ~~;). 3) seismo-active-fault survey and mapping, such as "The Himalayan Plan: active fault mapping at a scale of 1:~~50 ~~50,000 in the north China tectonic region and along the North-South seismic zone" and "Earthquake risk assessment of active faults in the key earthquake surveillance and prevention areas"~~; ~~. 4) Various other scientific researches. These projects ~~by ~~systematically ~~analyzing the~~analyze published scientific literature, remote sensing data, field surveys, and dating samples from geological profiles, trenches, and boreholes to ascertain accurate geometric and activity kinematic parameters, as well as mechanical properties of the studied active faults~~Accurate geometric and activity kinematic parameters as well as mechanical properties for the studied active faults are identified in those projects by systematically analyzing the published scientific literature, remote sensing data, field surveys, and dating samples from geological profiles, trenches and~~ boreholes (Xu et al., 2015). A professional panel then reviewed the obtained evidences and parameters and rechecked the final results of these four types projects.~~ to ensure reliability~~. In every project, an overall prospecting-and-surveying-process database is built to record all project data from beginning to end. Those project databases include data associated with the geophysical prospecting, drilling, offset-landform measuring and age dating (e.g., cosmogenic nuclides, OSL, ESR, or ^{14}C used for dating offset-landform, and OSL or ^{14}C used for dating dislocated-strata in trench), as well as geometric and kinematic parameters of ~~the ~~exposed and blind faults, paleo-earthquakes, their occurrence ages and recurrence intervals. ~~The d~~Data types ~~include ~~within these regionwide databases comprise two-dimensional Geographic Information System (GIS) data, photographs, geological photos with ~~interpretated ~~interpreted faults and illustrations~~,~~, geophysical prospecting data, copyrighted electronic literature~~ with copyright~~, and scientific reports. By the ~~end ~~conclusion of 2019, the ~~project's total amount of data ~~cumulative data from these projects had amassed to~~reached~~ 7 Terabytes.

The China Active Faults Database (CAFD) ~~is ~~represents a comprehensive geospatial database ~~that summarizes~~consolidating the most reliable ~~results of~~outcomes from the ~~abovementioned ~~aforementioned projects, ~~based ~~predicated on two ~~basic~~

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fundamental databases with ~~accuracy~~ accuracies of 1:50,000 for single active fault mappings and 1:250,000 for regional active fault distributions. The publicly accessible web-based query system ~~is open to the public and shares~~offers the latest ~~version~~ iteration of China's active fault database (CEFIS (V2)). Section 2 introduces the history and development of nationwide active fault maps and databases in China. Data acquisition, ~~data~~ resources, ~~data~~ processing, ~~database~~ compilation, and ~~data~~ quality are discussed in Section 3. ~~In addition~~Additionally, Section 3.9 presents several classical application cases in ~~Section 3.9~~ are presented to ~~demonstrate~~ underscore the extensive ~~use~~ utility of the database. The construction, function, performance, and usage of the web-based active fault query system are described in Section 4. System users can ~~browse~~ peruse and query fault information, obtain data from the Web Feature Service (WFS) and Web Map Service (WMS) servers in GIS software (such as ArcGIS and QGIS), and add active faults as layers in their web applications.

2 Nationwide active fault maps and databases

~~Different~~ Various organizations and experts have compiled the nationwide active tectonics and fault maps of China ~~during~~ at different ~~periods~~junctures. ~~Every~~ Each map summarized all of the research as much as possible before its publication date. ~~Those maps,~~ Maps such as the "Spatial distribution map of active tectonics and strong earthquakes in China (1:~~3~~ 3,~~000~~ 000,000)" (NEIZMT, 1976), "Map of the major tectonic-system activity and strong earthquakes epicenter distribution in China (1:~~6~~ 6,~~000~~ 000,000)" (NEIZMT, 1978), "Seismotectonic map of China (1:~~4~~ 4,~~000~~ 000,000)" (GICEA, 1979), and "Lithospheric dynamics map of China and adjacent sea area (1:~~4~~ 4,~~000~~ 000,000)" (Ma, 1987), ~~had~~ systematically ~~summarized~~ synthesized the latest research achievements ~~at specific~~up to their respective periods.

In the ~~past ten years~~last decade, the most influential nationwide active fault maps have been "The Active Tectonic Map of China (1:~~4~~ 4,~~000~~ 000,000)" (Deng et al., 2007) and "Seismotectonic Map in China and its Adjacent Regions (1:~~4~~ 4,~~000~~ 000,000)" (SMCAR; Xu et al., 2016). Deng et al. (2007)~~–~~ has been widely ~~shared with~~disseminated among scientists, specialists, and the general public over the past 10 years, ~~although~~ albeit not being available online. Its earlier version was integrated into the early version of Active Faults of Eurasia Database (Trifonov et al., 2004), ~~of which~~ an updated version of which was published in 2022 (Zelenin et al., 2022). ~~Currently~~Presently, the database ~~can be~~is freely ~~downloaded~~ downloadable online (NEDC (sub-center in IG, CEA), 2023), and scientists have updated this map ~~based on~~with new findings. For ~~example~~instance, Wu et al. (2018) compiled a "spatial distribution map of active faults in China and its adjacent sea areas (1:~~5~~ 5,~~000~~ 000,000) (2018)" by synthesizing ~~past decadal~~ publications in Chinese and English from the past decadal and 15-year research on active faults ~~achieved~~ conducted by the Institute of Geomechanics in the Chinese Academy of Geological Sciences.

The SMCAR (Xu et al., 2016) is a subproject of the 5th generation "Seismic ground motion parameter zonation maps of China" and is one of the four essential maps of the Chinese mandatory standard GB/T 18306-2015. This standard aims to develop seismic ~~fortification~~ design criteria for ~~anti-earthquake~~ seismic-resistant design in ~~different~~ various regions. The SMCAR collected the latest re-activation ages of faults from the previously introduced nationwide maps and some public or unpublic data. The SMCAR is now open to the public on the web system of the 5th generation “Seismic ground motion parameter zonation maps” (GB18306, 2023), and it has a geospatial database edition in addition to print and Joint Photographic Experts Group editions. This database integrates seismically active faults in China and adjacent regions and is also known as CAFD (2015). After geospatial correlation ~~by~~ using remote sensing images in the WGS84 coordinate system, its spatial accuracy ~~was better than~~surpassed that of previous ~~congeneric~~ analogous maps and datasets. The fault data ~~included the~~encompass fault attributes ~~of the~~such as name, main characteristics, and faulting age. A simplified version is ~~applied to construct~~utilized in constructing a probabilistic seismic hazard model for Mainland China (Rong et al., 2020).

3 Latest version of China Active Faults Database

3.1 Active faults database compilation workflow

The CAFD (~~2022~~2023) presented in this paper, which is based on the most reliable results of the projects introduced in Section 1, is an updated version of the CAFD (2015). The compilation workflow of the database is illustrated in Fig. 1.

The data used to update the nationwide CAFD (2015) are obtained from 120 regional project databases and research on active fault ~~surveys~~, earthquake surface rupture investigations, and published literature in the past ~~20 years~~two decades. All these databases~~The 120 regional project databases~~, ~~are obtained and produced under~~adhere to the same technological ~~system based on~~framework and are generated under well-established ~~knowledge~~ principles of active fault surveys (Sections 3.2-3.4), aligning with ~~and meet~~ the technical ~~demands~~ requisites of the Chinese mandatory standard (GB/T 36072-2018). ~~Every~~ Each regional project database ~~uses~~ adheres to the ~~same~~ identical data schema and standard as recommended by the China Earthquake Administration (GB/T 36072-2018; DB/T 53-2013; DB/T 65-2016; DB/T 81-2020; DB/T 82-2020; DB/T 83-2020). All parameter values of the fault data are ~~calculated using the same~~computed following systematic criteria and definitions (Section 3.7). ~~As~~ Given the uniformity data definition, schema, and acquisition method ~~are the same~~, there ~~is~~ exists no information ~~gap between~~disparity among these project databases. All data are processed using the same workflow. First, multiple-scale active fault data are extracted from different databases. Second, they are used to update the geometric shapes and attributes of the corresponding fault data in a nationwide database. Finally, the updated database (~~2022~~2023) is translated into English, adjusted for deployment, and released online (Sections 3.4 and 3.6).

The CAFD (~~2022~~2023) is ~~obtained from~~a culmination of numerous surveys (Section 3.5) and research endeavors~~references~~ (Xu et al., 2008a, 2008b, 2009a, 2009b; Chen et al., 2009; Xu et al., 2014a, 2014b; Xu et al., 2000; He et al., 2013; Shu et al., 2016, 2020; Li et al., 2019), ~~. It reflects~~ encapsulating the current state of the integrated knowledge ~~based on seismically active~~derived from seismic fault surveys in China.

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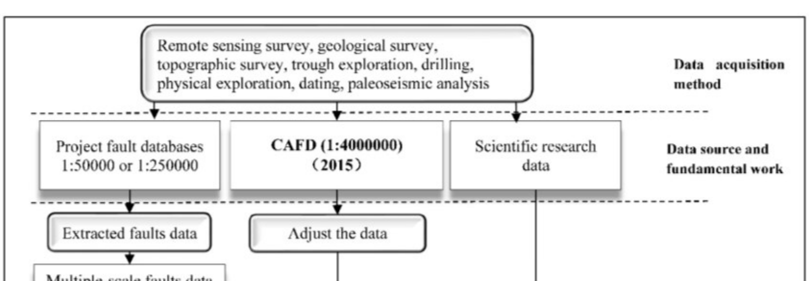

Figure 1: Workflow to construct the China Active Faults Database

3.2 Overview of data acquisition and methods

~~L~~The location, ~~geometric~~motion type, and kinematic parameters of ~~the~~ faults stored in the nationwide CAFD (2015)(1: 1:4,000,000) (Xu et al., 2016) and regional survey project databases (scale: 1:~~250~~ 250,000–1:~~50~~ 50,000), are ~~obtained~~ acquired through a combination of methodologies including remote sensing data interpretation, geological field surveys, trenching, drilling, geophysical prospecting, dating, and paleo-seismic analysis. However, it's noteworthy that the nationwide CAFD (2015) ~~had different~~exhibited differing accuracies ~~from~~ compared to the regional survey project databases. The horizontal accuracy of the nationwide database, on the scale of 1:4,000,000, is ~~about~~ approximately 12.8 kilometers (GB/T 33178-2016). The nationwide CAFD (2015) (Xu et al., 2016) is based on previous studies. In earlier research, the low-resolution seismic petroleum exploration profiles caused the low accuracy of the interpreted top breakpoints. Because of that, the accuracy of positional precision of the blind faults was not precise. Additionally, limitations imposed by~~The~~ locator devices with ~~a low~~lower positioning accuracy ~~limited the accuracy of positional precision of the exposed faults. The~~and reduced observation site~~s had a lower~~ density ~~than currently because~~due to~~ of less~~ funding~~, thereby causing a low~~constraints further impacted positional accuracy. ~~The horizontal accuracy of~~Conversely, survey mapping projects ~~on a scale of 1:50000 is~~at scales of 1:50,000 exhibit a horizontal accuracy of 37.5 meters~~.~~ (GB/T 33177-2016), ~~and~~ while~~the~~ urban active fault survey projects ~~on~~ at 1:250,000 ~~is~~ exhibit a horizontal accuracy of 200 meters (GB/T 33178-2016). The regional fault survey project databases (scale: 1:~~250~~ 250,000–1:~~50~~ 50,000) are based on quantitative methods written into the Chinese mandatory standard in 2018 (GB/T 36072-2018). These were classified as the exposed fault survey method (Section 3.3) and blind survey method (Section 3.4), and guaranteed a better data quality and accuracy than the nationwide CAFD (2015) (Xu et al., 2016).

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3.3 Exposed fault survey method

The exposed faults ~~refer to the faults having~~are those with surface expressions (such as linear fault scarp, offset gullies, and folding) or fault outcrop. Within~~In~~ the ~~present-day~~contemporary fault database, we only strengthen the locations, kinematics~~motion mode~~, and ages of these near-surface faults. The fault geometry or dip~~ping~~ angle, as suggested by seismic data, was not included. For the exposed faults with surface traces, remote sensing and ~~DEM~~Digital Elevation Model (~~Digital Elevation Model~~ DEM) data are ~~used first~~ initially utilized to map ~~the~~ fault traces and ~~create~~ generate an initial distribution map of ~~the~~ active faults. Then, combined with the field surveys, the locations of the faults in this initial map are verified, corrected, and recorded. Finally, a systematic workflow ~~method~~ that combines geomorphological surveys, stratigraphic analyses of the geological cross sections, trench stratigraphic logs, sample dating from terraces and trenches, and paleo-earthquake identification are used to obtain the latest faulting ages and kinematic parameters of the mapped active faults (DB/T 53-2013; Chen et al., 2016; Sun et al., 2017; Shi et al., 2019, 2022; Guo et al., 2021; Huang et al., 2021a).~~In~~ Within this ~~systematic method~~workflow, accurately locating ~~the~~ dislocated strata, samples, and trenches ~~are accurately located in~~within typical offset landforms is crucial. ~~The number of paleo-earthquake events and the motion mode of faults are visualized in the trenches. The age of fault activity is determined by the ages of dislocated strata, measured by dating methods, including radiocarbon (^{14}C), cosmogenic nuclides (^{10}Be), and luminescence techniques.~~The dislocated strata, visualized in the trench, reveal the number of paleo-earthquake events and the kinematics of faults. The ages of the dislocated strata, measured by dating methods, including radiocarbon (14C), cosmogenic nuclides (10Be), and luminescence techniques, determined the age of fault activity. These results were stored in those regional-scale survey databases.

The Fodongmiao-Hongyazi Fault, mapped at a scale of 1:50-,000 (Yang et al., 2018a, 2018b, 2020; Huang et 180 al., 2021a, 2021b), ~~can be taken~~serves as an example of~~for~~~~Taking the Fodongmiao–Hongyazi Fault, which is mapped at a scale of 1:50 000 (Yang et al., 2018a, 2018b, 2020; Huang et al., 2021a, 2021b), as an example for~~ the quantitative technical demands outlined in the Chinese mandatory standard (GB/T 36072-2018). First, remote sensing images with meter-level resolution (Quickbird, worldview, SPOT, ~~and so on~~etc.) and DEMs with horizontal and relative vertical resolutions of ⩽ 37.5 m (SRTM 1 Arc-Second DEM, ARSTER-II DEM, etc.~~SPOT, and so on~~) were used to mark surface deformations or offset landforms (fault scarps, dislocated gullies, fault valleys, pull-apart basins, pressure ridges, terraces, alluvial or fluvial fans ~~and so on~~) and plan geological survey sites, lines, and areas. Following these marks and positions, the fault could be traced along ~~the fault~~its strike, and the coordinates of the exposed fault site are precisely recorded by using Global Navigation Satellite System and hand-held GPS receivers. The average interval of coordinate-recording sites is 500–2 000 m, but if the surveyor ~~was~~ canable to access a site, an interval of 500 m is required (Fig. 2; DB/T 53-2013). The density of the recorded sites controls the geometric accuracy of the fault data. The horizontal location error of every recorded site was less than 15 m. If the surface deformations or offset landforms disappear in some areas, the approximate fault location should be taken from the original interpretation of the high-resolution remote sensing images and DEM data. Subsequently, the next exposed fault segment is searched by traveling across the region in a “Z” route. When the next fault segment is identified again, the fault

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should be traced along its strike. After these steps, the geometry of the fault trace is finally confirmed on the map. Once the fault trace is ascertained, the fault is ~~separated~~ divided into segments based on the geological landforms, geometric structure (straight, curved, bent, etc.), displacement distribution, seismic rupture characteristics, or signs of fault activity, so that each section is ~~relative~~ relatively independent. Along the key segments, typical offset landforms should be selected for further geomorphic and topographic measurements (Fig. 3a & c). In every independent segment, dislocated strata, samples, and trenches are accurately located, and the number of paleo-earthquake events is visualized in the trenches (Fig. 3b and d). ~~The ages of dislocated strata are measured by dating methods~~ Dating of dislocated strata only provides maximal age of rupturing event. To get more reliable age of the event we have to date both ruptured and non-ruptuted units. Common dating methods include radiocarbon (^{14}C), cosmogenic nuclides (^{10}Be), and luminescence techniques. The fault is ~~separated~~ divided into segments based on the mapped geometry. The ages obtained from a single geometry segment presented the age of this segment. ~~It determined the latest active age of the fault, although may not be the rupture behavior.~~ They are used to identify whether or not a fault is active, to calculate its slip rate during a certain period~~, to determine when a paleo-earthquake occurred, the paleo-earthquake recurrence interval, and the elapsed time of the last earthquake of the corresponding fault segment~~.

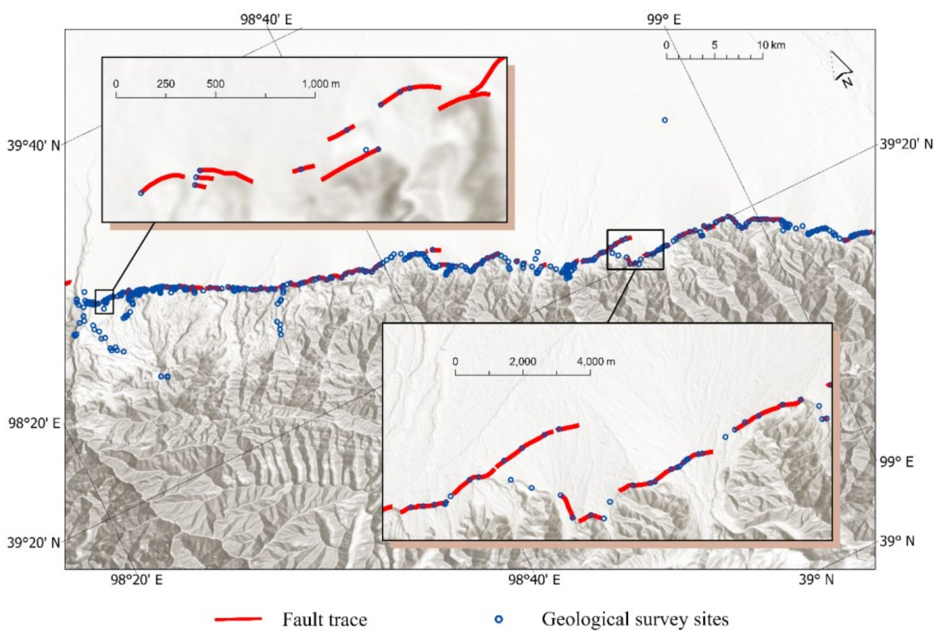


Figure 2: Survey sites for mapping of the Fodongmiao–Hongyazi Fault. The average interval of coordinate-recording sites ranges from 500–2 000 m. The fault belongs to the Qilianshan thrust fault zone at the northeastern margin of the Tibetan Plateau.

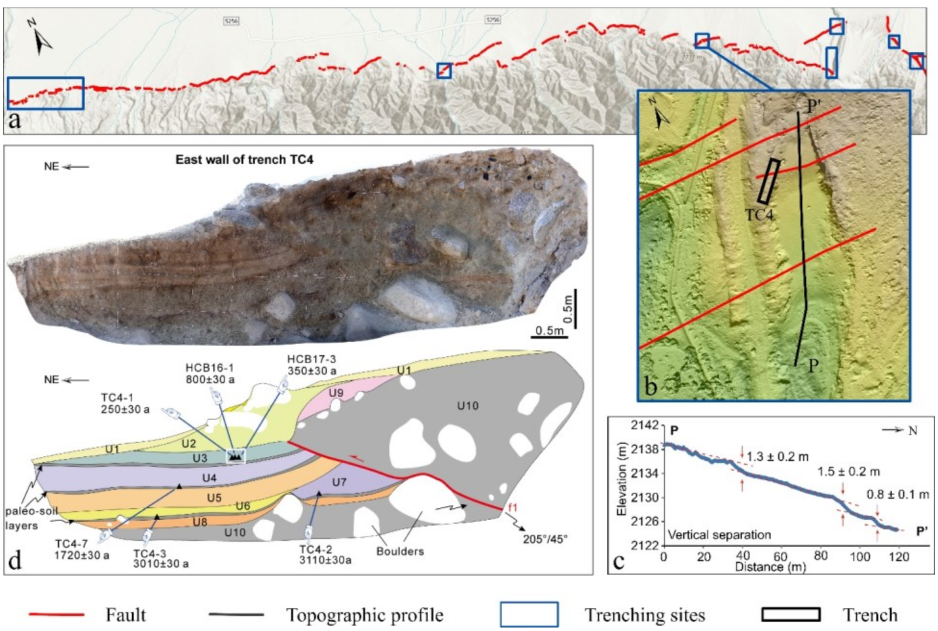


Figure 3: Key fault segment surveying example from the Fodongmiao–Hongyazi Fault (red line). (a) Distribution of the key fault segments in which geomorphic measuring, trenching, sample collecting, and paleo-earthquake trenching sites are marked by dark blue rectangles; (b) Locations of trench TC4 and topographic profile P-P′ are represented by black rectangle and black line, respectively; (c) Topographic profile (P-P′) showing fault offsets (adapted from Huang et al., 2021b); (d) Interpretation of the east wall of trench TC4 in detail (adapted from Huang et al., 2021b).

3.4 Blind fault survey method

The buried faults are those that ~~don't cut to the~~lack near-~~-~~surface exposure, ~~have no surface expression, and are possibly covered by the~~potentially concealed by overlying sediments or rock~~s~~ formations. Firstly, we collected petroleum exploration profiles, historical earthquakes, and published ~~references~~literature. The location of the blind faults was inferred from the collected petroleum exploration profiles. Secondly, the historical earthquakes and published references about tectonic settings helped to figure out the faults associated with earthquakes. Thirdly, a comprehensive multi-level exploration method with geophysics and drilling sites near the collected petroleum exploration profiles was applied to determine its exact near-surface location and the position of the uppermost ~~displaced~~ breakpoint of the major blind fault. Then samples obtained by drilling and dating techniques of the displaced and un-displaced strata and their dated chronological ages were used to identify their ~~late~~ Late Quaternary activity. This method ~~consists of~~encompasses multi-level seismic exploration, joint drilling to ~~construct~~ establish~~a~~ fault-across geologic<u>al</u> section<u>s</u>, trenching, and other technologies ~~to detect~~aimed at detecting ~~the~~ blind active faults from deep to shallow depths~~or even directly to the near surface~~.

In this study, the blind Yinchuan active fault ~~is used~~serves as an illustrative example (Fig. 4; Chai et al. 2006, 2011; Liu et al. 2008) to ~~describe~~ elucidate the quantitative technical ~~demands~~ requirements outlined in the Chinese mandatory standard (GB/T 36072-2018). Firstly, the seismic petroleum exploration profiles are used to reveal the approximate location of the target fault at a depth of hundreds of meters and the bottom of the Quaternary, marked by the shallowest continuous seismic reflection layer. Based on this information, a set of shallow seismic exploration profiles (in an interval of ≤ 2.5 km) is set up on the approximate ground to detect the depth of the uppermost point of the target fault. Secondly, two boreholes are drilled on both sides of the detected target fault to preliminarily verify the existence of the target faults (Fig. 5). During this exploration phase, the borehole number is gradually increased on both sides of the target fault to locate the depth of the uppermost points of the faults (Fig. 6; Chai et al., 2006; Lei et al., 2008; Wang et al., 2016). It requires at least 3 boreholes on each fault wall, with an interval of 5–45 m. The distance between the two boreholes on both sides of the target fault should be less than 10 m. Also, at least one borehole is required to penetrate the bottom of the Upper Pleistocene on each side, and the final depth of other boreholes is needed to be 10 m beneath the uppermost points determined by the shallow seismic exploration (GB/T 18306-2018). The exact location and faulting age of the target blind fault could be identified by strategic analysis and sample dating of the borehole cores. If the depth of the uppermost points determined by the joint drillings is less than 10 m deep from the ground, more information on the blind fault geometry and paleo-earthquakes could be revealed by trenching. The mapped blind fault trace ~~is a line of~~comprises vertically projected uppermost points on the ground, ~~which are~~ obtained ~~by~~ through the comprehensive multi-level exploration ~~method~~approach.

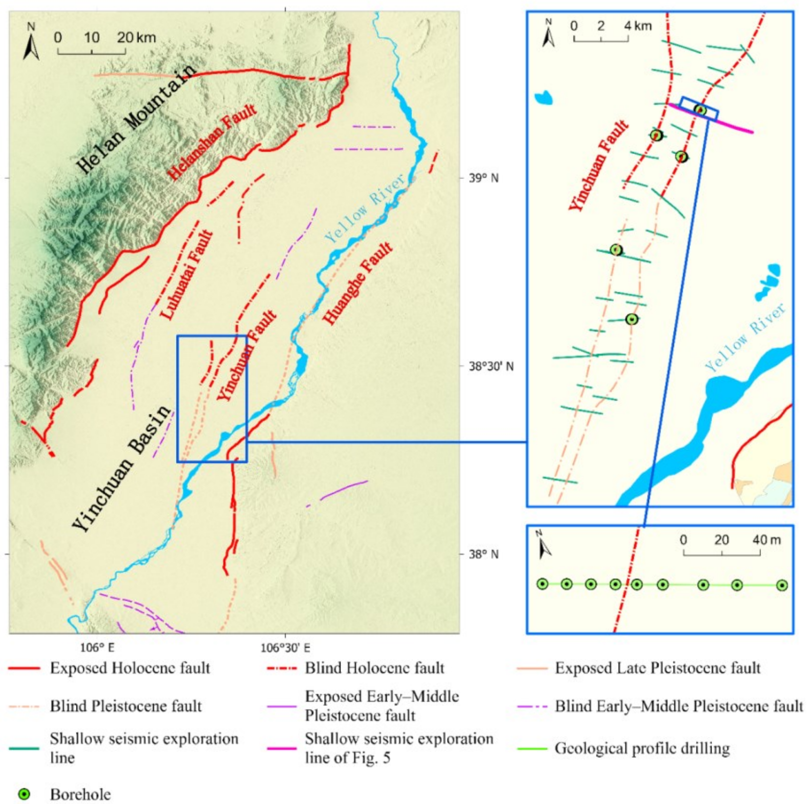
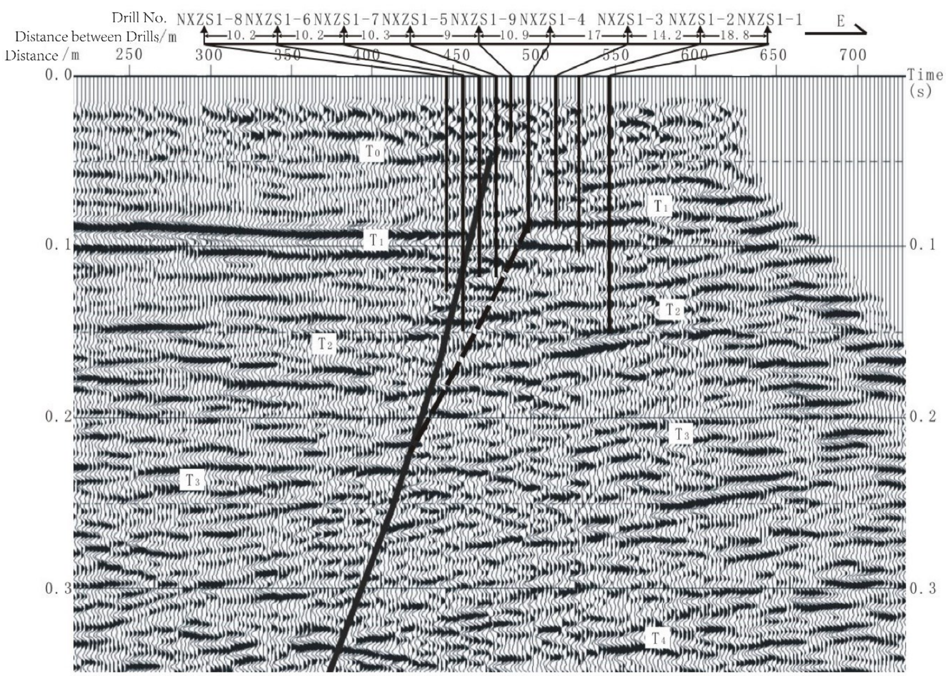


Figure 4: Map of the blind Yinchuan Fault in the Yinchuan Basin located in the northern portion of the North-South seismic zone in China.


Drill No.
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NXZS1-1
E
Distance between Drills/m
10.2
10.2
10.3
9
10.9
17
14.2
18.8
Distance /m
250
300
350
400
450
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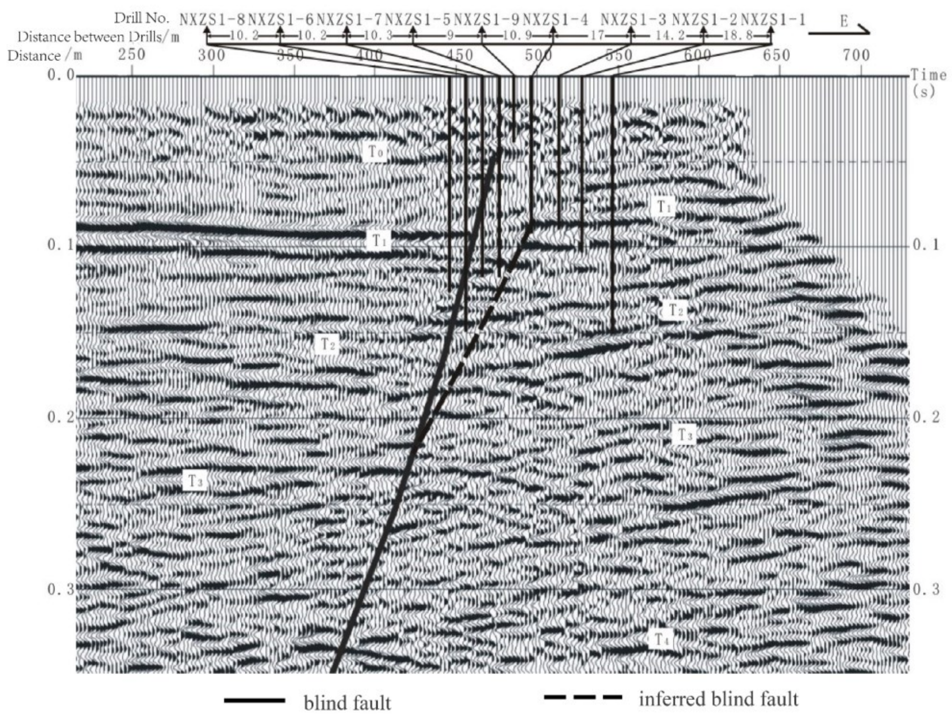

Figure 5: Approximate locations of the detected target fault and boreholes along a seismic exploration profile (adapted from Chai et al., 2011, Xu et al., 2015).

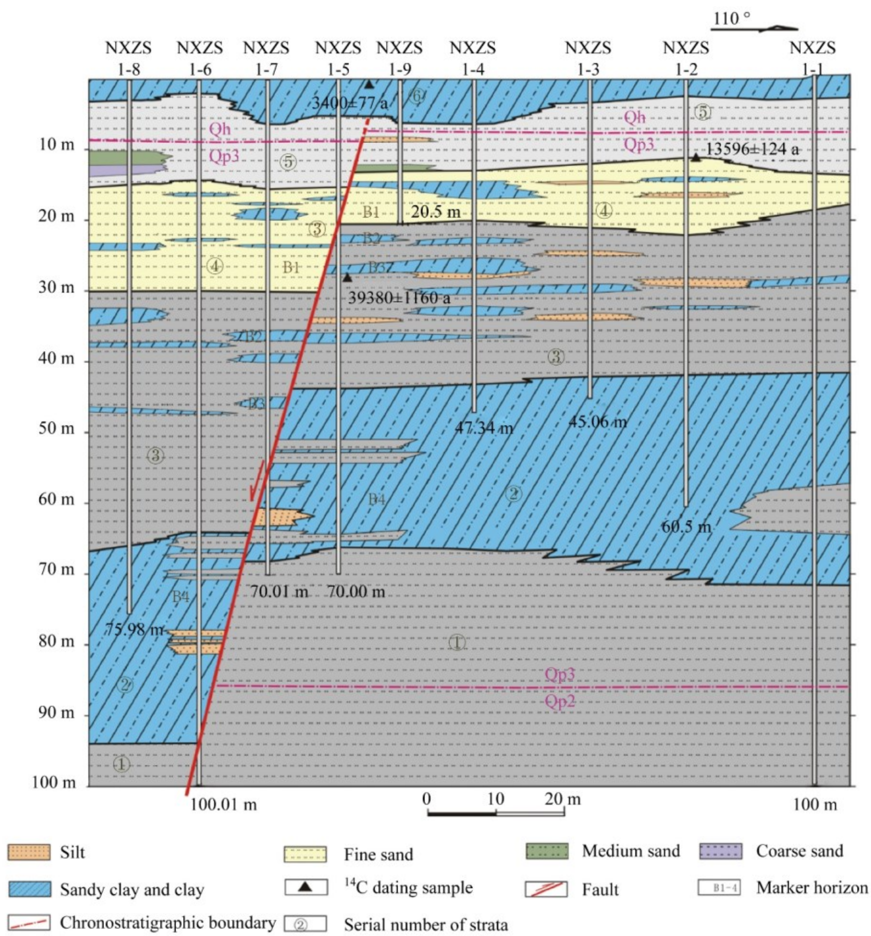

Figure 6: Joint Drilling geological cross-section at Xinqushao Village in the Yinchuan Basin (adapted from Lei et al., 2008; Chai et al., 2011).

3.5 Data sources and fundamental works

The CAFD (~~2022~~2023) was updated by integrating new data from the projects of active fault surveying in urban regions, seismically active fault mapping at a scale of 1:~~50~~ 50,000 in North China and the North-South seismic zone, ~~and~~ seismic risk assessment of ~~the~~ active faults in ~~the~~ key earthquake surveillance and prevention areas, and other scientific research endeavors (Fig. 7). These projects are introduced in detail below:

The projects ~~of~~ on active fault surveying and seismic risk ~~assessing focus on locating~~ assessment primarily aim to identify ~~the~~ blind or exposed seismically active faults and ~~assessing the~~evaluate earthquake risk in large- and medium-sized cities, as well as ~~and~~ in the key earthquake surveillance and prevention areas~~.~~, Conversely, ~~while the project of~~ active fault mapping projects focus on ~~locating such~~pinpointing detailed locations of exposed seismically active faults ~~in detail for~~to facilitate land-use planning and utilization (Xu et al., 2015; Zhu et al., 2005; Chai et al., 2011; Liang et al., 2013; Shen et al., 2016; Hou et al., 2012; Chen et al., 2013; Yang et al., 2010). ~~The f~~Fundamental works ~~of~~ within these projects encompass five main aspects~~mainly include five parts~~: (1) ~~initially identifying~~identification of fault activity, (2) ~~detecting~~ detection of deep faults structures ~~of the fault in~~within the crust, (3) ~~assessing~~ assessment of earthquake risk ~~possibility for the~~associated with ~~identified~~ major identified faults to ~~judge~~ discern seismically active faults, (4) ~~locating the detailed~~precise delineation of geometry ~~of the~~for major seismically active faults, and (5) evaluation of earthquake hazards ~~on the~~posed by seismically active faults. Achievements of these projects include maps~~, which demonstrate the~~illustrating regional distribution of the active faults at a scale of 1:~~250~~ 250,000 and detailed fault traces of a single active fault at a scale of 1:~~50~~ 50,000, exploration reports, project databases, and information systems (Xu et al., 2015). All of the data obtained from the fundamental works and the project achievements are carefully reviewed by three to eight experts from a professional panel. Therefore, the data results were credible. These projects have been carried out in ~100 cities, including 26 provincial capitals and municipalities, until March 2020. Twenty urban active fault survey project databases (Table A1), which were conducted from 2002 to 2009 in Beijing, Tianjin, Shanghai, Nanjing, Ningbo, Zhengzhou, Qingdao, Hohhot, Taiyuan, Xi'an, Yinchuan, Lanzhou, Xining, Lhasa, Kunming, Urumqi, Haikou, Guangzhou, Changchun, and Shenyang (Fig. 7), are earliest fault data published and released to the public (Xu et al., 2015), and are also used to update the nationwide active fault database.

Active fault survey and mapping projects ~~on~~ at scales of 1~~:~~ :~~50~~ 50,000 and 1:~~250~~ 250,000 ~~are funded by~~received funding from the China Earthquake Administration~~. The goal is to obtain the exact~~, with the objective of acquiring precise location, spatial distribution, geometric and kinematic parameters, activity ages, slip rates, paleo-earthquake events and their recurrence intervals, and ~~the~~ elapsed time ~~of~~ since the last surface-rupturing event on the faults. These projects followed the procedure introduced in Sections 3.2-3.4 and meet the quantitative requirements of mandatory and recommended standards (GB/T 36072-2018; DB/T 53-2013; DB/T 65-2016; DB/T 81-2020; DB/T 82-2020; DB/T 83-2020). A professional panel reviewed the field data and mapping results ~~to guarantee data quality~~. ~~In~~ For this study, ~100 mapped faults (Fig. 7) in North China, the North-South seismic zone, and the ~~Tianshan~~ Tien Shan region are selected to update the nationwide active fault database (Table A2).

The focus of sScientific research projects has been placedfocused on answering addressing specific scientific questions aboutinquiring concerning active faults and earthquakes. In those These projects, delve into seismo-tectonics and seismo-genesis at some sites or in some regions are studied based on the fault's geometric and kinematic features of fault within specific sites or regions. The results are credible and provide parameters such as reliable slip rates, paleo-earthquake sequences, the potential magnitudes of future earthquakes, coseismic slips, and their distribution along the strike of a seismogenic active faults. To update the nationwide active fault database in this study, data from the 2021 M 7.4 Madoi Earthquake investigation (Chen et al., 2022), 2008 M 8.0 Wenchuan Earthquake investigation (Xu et al., 2008a, 2008b, 2009a, 2009b; Chen et al., 2009), 2014 M 6.5 Ludian Earthquake investigation (Xu et al., 2014a, 2014b), Xia-Dian Fault survey (Xu et al., 2000; He et al., 2013), and research on the Tanlu Fault (Shu et al., 2016, 2020; Li et al., 2019) were used utilized (Fig. 7).

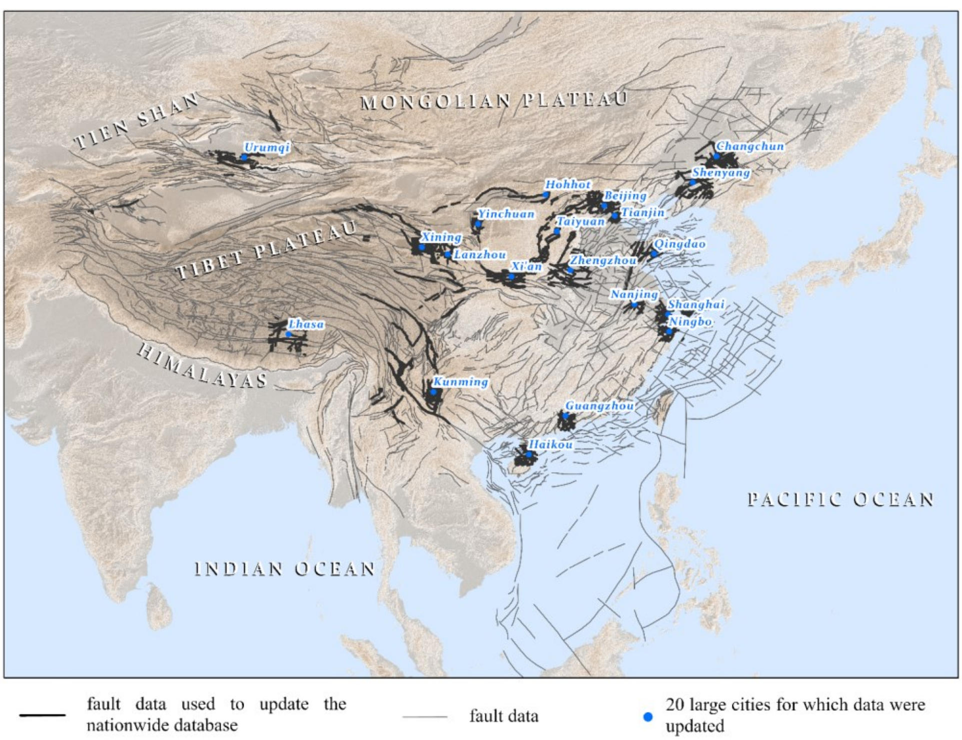

Figure 7: Sketch map of updated fault data in China.

3.6 Data processing

The CAFD (2015), along with project databases of active fault surveys and mappings in ~~different~~ various regions ~~and the scientific research data,~~ ~~have been established. The data are~~constituted a complex dataset characterized by~~, with~~ multiple scales and varying accuracies, ~~and the~~with a considerable total data size ~~is large~~. As ~~introduced~~ detailed in Section 1, the databases of active fault surveys and mappings ~~include~~ comprise ~~115~~ 100 sub-databases, totaling ~~with a total size of~~ ~7 Terabytes of data. All data ~~are supervised~~undergo rigorous supervision and review~~ed~~ by professional panels ~~to ensure they are all highly accurate and reliable~~. For the primary ~~purpose~~ objective of ~~introducing~~ presenting the ~~newest~~ latest integrated achievements in this study, the individual reliability of fault data is not ~~individually described~~delineated. Instead, the individual data source of fault data is encompassed. To integrate ~~those large~~these extensive datasets into a unified database with ~~the same~~consistent data criteria and schema, we first integrated those project databases constructed on a regional scale and then updated the national-scale CAFD (Fig. 1). ~~Major~~ Significant updates ~~of~~ to the 1:~~4~~ 4,~~000~~ 000,000 nationwide database include the refinement of activity ages and fault locations ~~of~~ for the late Pleistocene and Holocene faults.

The project databases of active fault surveys and seismically active fault mappings are constructed by using the same criteria. They have the same data schema and use unified, well-established acquisition methods. ~~Therefore, the~~Consequently, fault data from these two types of databases can be processed using ~~the same~~consistent procedures, with ~~a small workload~~minimal effort required for data cleaning and mining. The first step involves extracting multi-scale fault data from the 120 project databases. The second step is to integrate them. These projects are ~~systematically~~ strategically planned ~~so that, theoretically,~~ to avoid overlap of fault data with the same scale ~~do not overlap~~. If the same region contains more than one fault trace, only the largest-scale data are used for integration. As the scales of the new well-mapped fault traces are equal to or even larger than 1:~~250~~ 250,000, they are too complex to be integrated into 1:~~4~~ 4,~~000~~ 000,000-scale data. Therefore, the third step is to simplify the fault traces. In large-scale fault data, a fault is generally segmented for detailed investigation; hence contiguous segments may have different activity ages. One of the most important applications of the database is hardcopy or electronic image maps for earthquake emergency response (Wu, et al., 2021). The reference scale of the hardcopy maps is about 1:~~4~~ 4,~~000~~ 000,000~1:~~1~~ 1,~~000~~ 000,000. If the contiguous segments within 2 cm have different activity ages, they will be merged for map generalization. When integrated into the national scale fault data, two or even more small contiguous segments may be merged into one. Under this condition, the activity age of the merged fault trace is the same as the latest of the merged segments. For example, the blind Yinchuan fault (1:250 000) is divided into the Holocene north segment (Fig. 4a, red dotted line in the blue rectangle) and the late Pleistocene south segment (Fig. 4a, orange dotted line in the blue rectangle). The total length of those two segments is 80 km, which is only 2 cm on a 1:~~4~~ 4,~~000~~ 000,000 scale map. Therefore, the two segments are merged into a Holocene one.

Scientific research ~~has mainly focused on one segment~~predominantly focuses on individual segments or a limited number of surveying sites for ~~one~~ a given fault. ~~Those~~ These data ~~are used~~serve to supplement the CAFD (~~2022~~2023), to complete and correct the national-scale fault data using a similar ~~method~~methodology. While~~T~~ the CAFD (2015) ~~was based on~~shares the same data definition and acquisition methods as previously described, ~~but~~ its data schema slightly differs from ~~the~~ that of project databases~~ of the fault surveys and mappings~~ concerning field names and domain values. Considering that the CAFD (2015) has fewer fault traces than the project databases, we adjust the CAFD schema to fit the project databases. Subsequently, the processed data introduced in the previous two paragraphs are smoothly integrated into the CAFD (~~2022~~2023). The CAFD (~~2022~~2023) is adjusted for deployment in the Web-GIS system before being published in the last step.

3.7 Data descriptor

The active fault database undergoes translation~~is translated~~ into English prior to deployment~~before being deployed~~ in the system and global release~~,d~~ facilitating access for~~so~~ scientists and engineers ~~could use it~~ worldwide. Its fields encompass~~include~~ the fault zone name, fault name, fault segment name, kinematic features, and activity age (Table A3).

The fault data are graded ~~based on~~according to size and characteristics using the fields of fault zone name, fault name, and fault segment name. A fault zone is a cluster of parallel~~large~~ faults ~~system~~ such as the Tanlu and Longmenshan fault ~~systems~~zone. In general, faults in the same ~~system~~ fault zone ~~matched~~ exhibit congruent in geometry and kinematics, together with accumulated crustal strains, or possibly connected in deep. A single-fault ~~system~~ zone consists of single fault or several faults. A single fault is further subdivided into multiple segments based on geometry. Each segment has specific and different geometric ~~and kinematic~~ characteristics and is a basic studied unit of a fault. ~~For example~~Take the Fodongmiao-Hongyazi Fault (FHF) as an example (Huang et al., 2021b)(Fig. 8). It is one fault of the northern margin fault zone of the Qilianshan mountains. ~~The fault traces of the~~Its west and middle segments ~~were in different~~exhibit divergent geometric patterns~~.~~: ~~T~~the west segment trace ~~has~~displays linear ~~characteristic~~characteristics~~.~~, while~~T~~ the middle segment trace ~~is~~resembles jagged ~~like a dog's~~ teeth. Moreover, ~~T~~the east segment~~, is separated with~~distinct from the middle segment, is delineated by an~~the~~ anticline~~,~~ and ~~turn~~follows a linear trajectory. ~~, …~~ ~~Each fault line data point belongs to one fault segment.~~ Not all faults ~~belong~~ are affiliated with~~to~~ a fault ~~system~~zone.

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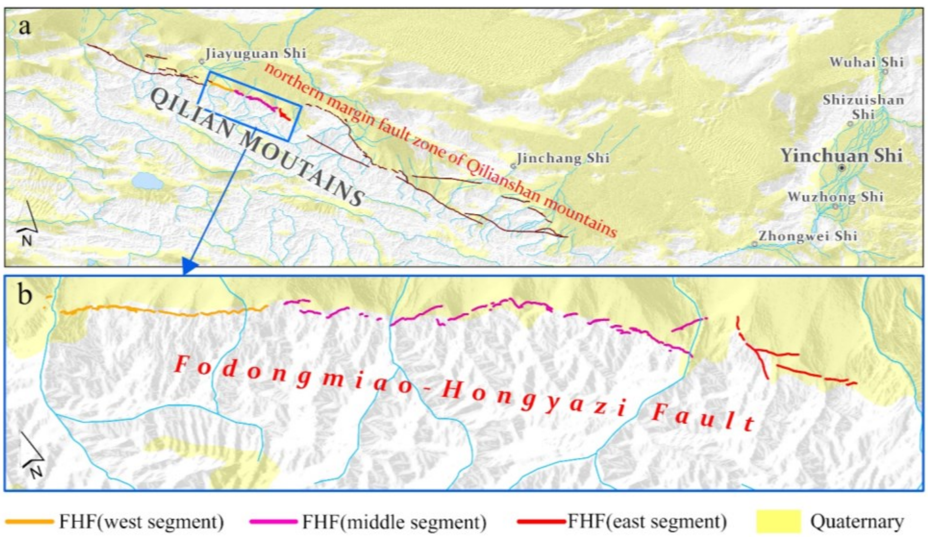

Figure 8: Map of (a) the northern fault zone of Qilianshan mountains, and (b) Fodongmiao-Hongyazi Fault.

Only some important active fault line data belonging to ~~a~~ fault ~~system~~ zones in block boundary zones are assigned ~~have~~ a "fault zone name". ~~Some~~ Additionally, highly ~~studied~~ scrutinized faults are ~~divided into segments~~ segmented and the corresponding fault line data have "fault segment names." ~~Because of~~ Given the ~~complications~~ intricacies and ~~massive~~ vast number of faults in China, the process of rating and naming must ~~be continued~~ persist.

The field named "feature" stores information regarding the motion type and visibility ~~from~~ of the fault on the ground. Based on the relative movement of the two walls, the faults were classified as normal, reverse, strike-slip, or oblique faults. Oblique faults consist of left- and right-oblique slip faults, with vertical components that might be either normal or reverse. Active faults are also divided into exposed and buried faults.

The active fault database is aimed at earthquake ~~hazard~~ disaster ~~reduction~~ prevention and focuses on the latest activity during the Quaternary. Therefore, faults are classified as the Holocene, late Pleistocene, middle–early Pleistocene and pre-Quaternary faults, denoted by the field "Age" (GB/T 36072-2018). The Holocene faults are those with active evidence from the Holocene or the past 12 000 years. For the late Pleistocene faults, active evidence exists in the late Pleistocene but not in the Holocene. The middle–early Pleistocene faults are those with the latest active evidence in the middle or early Pleistocene. For pre-Quaternary faults, active evidence is not available in the Quaternary. This means that no evidence showed that the fault displaced the ~~Quaternary~~ Quaternary landforms or sediments. There was also no Quaternary fault age information such

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as the ESR dating fault gouge. Major active evidence is based on the latest dislocated stratum. This method is introduced in Sections 3.3-3.4.

3.8 Quality discussion

The CAFD (20222023) collects the maximum amount of reliable data in the projects introduced in Section 3.5 launched by China Earthquake Administration, relative related to earthquakes with the primary objective of effectively reducing preventing earthquake hazards disasters by determining earthquake sources and carrying out active tectonic zonation. It performs well in terms of quantity and quality. The spatial correlation between faults and earthquakes with magnitudes greater than 6.5 is high. The amount of fault data is large. The database contains ~7 7,000 fault traces， among of which ~1 1,606 600 faults are named. The fault names were collected from published or unpublished papers, geological literature, or existing fault databases. There are, utilizing two primary naming methods. One is named after the mountains and rivers. The other is named after the place name (county, village, etc.).

Active fault surveys in China are difficult because the country is located in the intersection region of the Circum-Pacific and Eurasian seismic zones, resulting in complex continental tectonics, widely distributedwidespread distribution of active faults, strong intense neotectonics and earthquake seismic activityies, and inaccessible landformsterrain. The extent of seismo-genic fault research varies from region to region in China. For some faults with low research extent, their geometric and kinematic parameters remain unknown or imprecise. In the periphery and interior of the Tibetan Plateau, which was formed during the colliding collision ofbetween the Indian and Eurasian Plates, there the exist mega-strike-slip fault systems, such as the Altyn Tagh, east Kunlun and Xianshuihe Faults, the thrust fault systems, e. g. the Himalayan frontal, the Hexi Corridor and the Longmenshan thrusts, and as well as the North-South striking normal faults in the western western part of the Plateau existPlateau. The thrusts and strike-slip fault have also been developed at the northern and southern piedmonts and in its interior. In some regions in the Tien Shan (see Fig. 7)Tianshan and Tibetan Plateau due to the high altitude and snow-capped, it is difficult to carry out research work and obtain accurate fault data. There exist nNumerous oblique normal faults around the Ordos Block and strike-slip faults, such as the Tanlu fault in Eastern China exit too. Those faults are located in regions with dense urban construction and populations or thick Quaternary quaternary deposits. Therefore, it is difficult to find those fault traces on the ground and locate the blind faults underground. Besides, the spatial relationship and geometrical link of some faults, such as some segments of the Tanlu fault in Eastern China and some E-W trending faults in the Tibetan Plateau, also remain unclear.

Thus, the vector lines of such faults directly cross each other without expressing a geometrical link. In addition, research on marine and maritime island faults has been limited by surveying technology.

As Given that the Active Fault Database in China is primarily based on 1:4 4,000 000,000 data and wasbut updated by with 1:250 250,000–1:50 50,000 data, the total overall coordinate accuracy is similar comparable to the that of a 1:1,000,000 map in whichwith 1 mm is equal torepresenting 1 km in the real world, depicting and represents the width of the fault line symbol. The data precision is partially better than that of the 1:1 000 000 map because the reference is on a larger scale.

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~~Based on the discussion above~~In conclusion, the CAFD (~~2022~~2023) ~~is based on~~reflects the latest research on active faults and fault data integration. More investigations of active tectonics and fault systems should be carried out in China, and the nationwide database should be updated in the future.

3.9 Application

The CAFD (~~2022~~2023) and its previous versions have been widely used by the Chinese government, research institutions, and associated companies. The National Geomatics Center of China and the China Petroleum & Chemical Corporation take those data as reference ~~data to analyze~~material for analyzing the seismotectonic environment ~~for~~ within their information management systems. The national-scale Active Faults Database is the basic reference for compiling seismotectonic maps on ~~a~~ both regional ~~or~~ and national scales. Examples include the seismotectonic map of the Ordos block and its boundary zones (1:500 000; National Research and Development Program of China; No. 2017YFC150100), digital seismotectonic map of the northeastern seismic zone in China (1:1 000 000; a Spark Plan project funded by the China Earthquake Administration; No. XH18015), seismotectonic map of the Shanxi Province and its adjacent regions (1:500 000; a public service map produced by the Shanxi Earthquake Agency), and seismotectonic map of China (1:1 000 000; first comprehensive natural hazard risk investigation in China). ~~They are also used~~Furthermore, these data play a crucial role in earthquake emergency response services, monitoring services, forecasting services, and earthquake disaster prevention~~ supervised by~~, all under the supervision of the China Earthquake Administration. Since 2018, ~~T~~the database has been ~~delivered~~ provided to the earthquake response departments of the China Earthquake Networks Center for emergency actions~~ since 2018~~. In the same year~~2018~~, it was also ~~delivered~~ made available to the working research group of the post-earthquake prediction technology system, a key project in earthquake monitoring and forecasting from the China Earthquake Administration (Project No. 18440680117). In 2019, this database was transferred to the China Earthquake Disaster Prevention Center to establish the Data Center for Seismic Active Fault Surveys. The Institute of Geology, China Earthquake Administration (IG, CEA), has also produced seismotectonic maps during earthquake emergencies based on the database (Wu et al., 2021). ~~As~~The WFS service hosted in ~~the~~ our system ~~discussed in this study was released online,~~has been utilized by a commercial app (GeoQuater)~~ became available that uses the WFS service of this database as a thematic map~~. ~~The WFS service is stable on the application.~~

4 System Introduction

4.1 System performance and architecture

The China Earthquake and Fault Information System (CEFIS(V1), 2021), which has been ~~launched~~ available online and continuously updated since 2019, ~~provides~~ offers web services for ~~inquiring about~~querying earthquakes and active faults in China and adjacent regions. The CAFD (2015) has been released in the system. In 2021, the system was updated again by

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simplifying the interface, adding the English fields, earthquake base map, layer addition, and system sharing function. Additionally, ~~A~~a simplified ~~case~~ version of a regional active fault survey map (Wu et al., 2022), introduced in Sec 3.3, is also open to the public as a map service ~~in~~ within the additional layer list. This section ~~introduces~~ provides an overview of the architecture of the ~~URL's~~ current version (CEFIS (V2), 2023).

The system is ~~constructed~~ built on the ArcGIS Enterprise platform 10.6 using ArcGIS Web AppBuilder in the B/S mode and is ~~separated~~ divided into four layers (Fig. ~~8~~9) namely data, service, portal, and application layers. The data layer deploys the PostgreSQL database to store active fault and earthquake data. PostgreSQL, ~~is~~ a free open-source object-relational database system, ~~that~~ can be connected to an ArcGIS Server deployed in the service layer. The ArcGIS Server can publish data in the form of map and feature services, which ~~can be conveniently called~~are easily accessible through web applications. The ArcGIS Portal and ArcGIS Web Adaptor are deployed in the portal layer to provide WMS and WFS services and manage user access. The ArcGIS Portal provides intuitive what-you-see-is-what-you-get applications such as AppBuilder with ready-to-use widgets~~.~~, ~~These applications are used to construct a~~which enable the construction of map and three-dimensional scene applications on the web. The system discussed in this study is also ~~constructed~~ developed using ArcGIS Web AppBuilder. Supported by these technologies, the CAFD can be accessed ~~on~~ across various platforms ~~through~~ including desktop software, smartphones, and online sites.

Figure ~~8~~9: System architecture diagram.

4.2 Earthquake sequence data

The system uses earthquakes (M > 5.0) as a background to ~~show~~ illustrate seismic~~earthquake~~ activity on and around faults. The earthquake catalog sourced from the National Earthquake Data Center (NEDC) is converted into geographic vector data and deployed in the system (Earthquake sequence data from NEDC, 2023). ~~It~~ This dataset encompasses ~~contains~~ historical and instrumental earthquake records ~~of earthquakes that occurred before~~preceding June 2021. The system contains three earthquake layers~~.~~ ~~Those~~ corresponding to the three datasets ~~downloaded~~ obtained from the NEDC. The NEDC provides three datasets based on the followingspecific time periods: a historical earthquake catalog (before prior to ~1969.12.31.; Table A4), the earthquake catalog of from the China Earthquake Networks (CEN; 1970.1.1.-2008.12.31.; Table A5), and the official earthquake catalog from the CEN (2009.1.1.-2023.7.31.; Table A6). The historic earthquake catalog compiled by Gu (1983) includes destructive earthquakes (M ≥ 5.0) that occurred from 1831 BC to 1969 AD. The CEN earthquake catalog consists ofcomprises data from 88 National seismograph network stations (digital), regional someone-on-duty network stations (digital), and simulated network stations. The official earthquake catalog is from CEN, which is obtained from nationwide earthquake monitoring station networks consisting of comprising national and regional (31) station networks after post-January 1, 2009.

4.3 System usingusage

4.3.1 System interface and function

The system is a Web Map application that displays and queries the Active Faults Database of China and its adjacent regions. It is publicly available worldwide. The systemIts interface consists of comprises seven parts components (Fig. 910): (a) web map, (b) eagle-eye map, (c) attribute table, (d) browsing tools, (e) address geolocation tool, and (f & g) system tools. The language of the system interface is based ondetermined by the browser's default languagesettings. The data field values are presented in both English and Simplified Chinese in within the attribute table and Query dialogue. Thus, the system can be used by both EEnglish and Chinese-speaking usersnglish and Chinese users. Additionally, users proficient in languages such as French, German, Russian., etc. users are not English butcan also can use the system.

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Figure 910: System interface. (a) Web map displaying only fault traces in full extent view; when zoomed into the regional scale, earthquake epicenters will appear on the map. (b) Accordion overview map. (c) Accordion attribute table. (d) Navigation toolbar; the tools from top to bottom are zoom in, zoom out, default extent, zoom to the current position, full extent, previous view, and next view. (e) Address geolocation tool. System tools: (f) measurement, selection, inquiry, and layer addition (from left to right) and (g) legend, layer controller, base maps, and sharing (from left to right).

4.3.2 Data query and export

The system provides offers four methods for querying fault information: (1) The menu of within the attribute table window (Fig. 9a10a) provides a "filter" tool to query faults with certain conditions (Fig. 110a); (2) the second tool is a spatial selection tool (Fig. 9f10f) for fault and earthquake data (Fig. 10c11c); (3) the third tool allows fault queries by feature, activity age, or name under specific spatial conditions (Figs. 110b and 9f10f); (4) the address geolocation tool (Fig. 9e10e) can be used to zoom the map into a specific region and export the faults in that region (Fig. 10d11d). The system can exportsupports exporting the query results using diversethrough various methods (Fig. 1011).

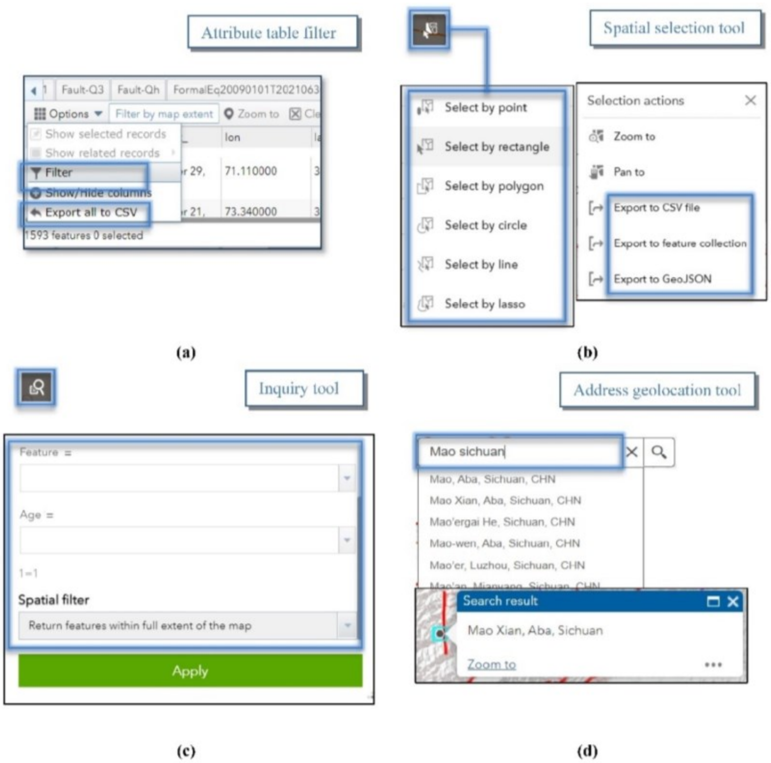
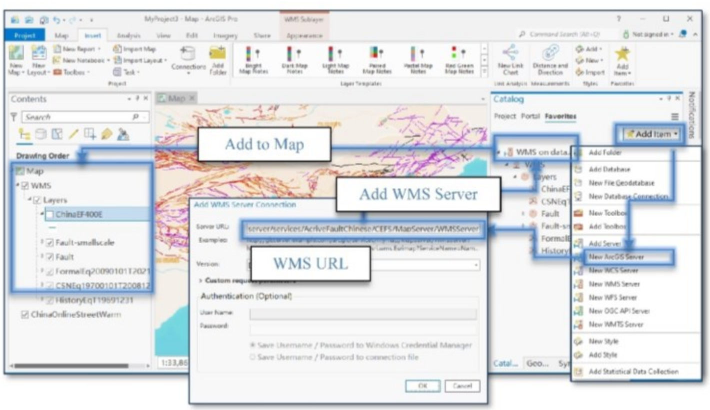


Figure ~~10~~11: Data query and export tools: (a) attribute table filter, (b) spatial selection tool, (c) inquiry tool, and (d) address geolocation tool (translated by Google Chrome).

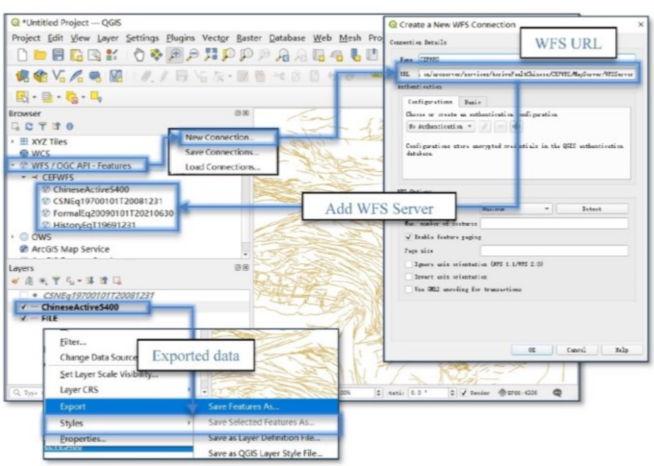
4.4 How to use the data service

The system publishes the Open Geospatial Consortium (OGC) WFS and WMS of the active fault database of China. The OGC WFS and WMS are dynamic services that ~~provide dynamic~~offer realtime maps on the web, ~~following the~~ adhering to OGC specifications~~ of the OGC~~. These services ~~allow~~ facilitate open and authentic access to web maps ~~to access diverse~~ across different platforms and clients~~ openly and authentically~~. Available operations of the WMS in the system in this study are GetCapabilities, GetLegendGraphic, GetSchemaExtension, GetFeatureInfo, and GetMapGetStyles. Compared with WMS, WFS provides greater data access, benefiting from its ability to insert, update, delete, retrieve, and discover geographic elements over HTTP in a distributed environment. The ~~A~~available WFS operations ~~are~~ encompass

GetCapabilities, DescribeFeatureType, GetPropertyValue, GetFeature, GetGmlObject, ListStoredQueries, and DescribeStoredQueries. In ~~other words~~esence, data can be browsed, queried, analyzed, and downloaded from the system, but not revised. Furthermore, ~~F~~fault layers can ~~also~~ be ~~added to~~integrated into GIS software for analysis through WMS and WFS, such as ArcGIS Pro and QGIS (Fig. ~~11~~12).



(a)



(b)

Figure ~~11~~12: (a) How to add WMS Server in ArcGIS Pro. (b) How to add WFS Server in QGIS and export data.

5 Conclusions

The CAFD (~~2022~~2023) ~~is integrated with~~integrates both the national-scale fault database and the latest decadal regional-scale fault survey data~~ and represents the most complete nationwide seismo-active fault data in China~~. The database, along with ~~and~~ its previous versions, have been widely applied in government departments, research institutes, and commercial companies. China is situated in the intersection between the Circum-Pacific and Eurasian seismic zones with numerous complex continental tectonics, active faults, and earthquake activity. However, ~~it is difficult to survey~~challenges persist in surveying or ~~locate~~ locating active faults in ~~some~~ certain regions due to inaccessible ~~landforms~~ terrain and anthropogenic activities. Active faults should be considered for earthquake ~~prevention and~~ disaster mitigation. Therefore, the database will be gradually updated in the future based on future references, and a later version may be released on the system if it is finished.

The first version of the web system (CEFIS (V1), 2021) has ~~operated~~ performed effectively~~well~~ for nearly 2 years and its second version (CEFIS (V2), 2023) was released in 2021 and has also been operating well. This study ~~introduces its~~delineates the architecture, interface, function, and usage of the system, serving as~~ to provide~~ a platform ~~to~~ for querying and ~~analyze~~ analyzing the integrated active faults database in China., ~~which stores~~This database encapsulates crucial information pertaining the location, latest activity age, ~~and geometric~~ and kinematic characteristics of the faults. The system can be used by both English and Chinese-speaking users. Additionally, users proficient in languages such as French, German, Russiancan also use the system.~~Although the interface environment is in the Chinese language, English-speaking users can also use the system introduced in Section 4.3.~~

Data and services are openly shared worldwide via the web system. The data can be downloaded from a browser or GIS software. A third-party application can link to and use the WMS and WFS services (CAFD WMS, 2023; CAFD WFS, 2023). Users can get help from the ArcGIS online document. Section 4.4 lists the available operations of the services.

6 Data availability

The CAFD and web system are accessible at CEFS (V2) under the DOI:
https://doi.org/10.12031/activefault.china.400.2022.db (Xu, 2022). The WMS (CAFD WMS, 2023) and WFS (CAFD WFS, 2023) services of the active fault are accessible online. The data are downloadable through diverse platforms and clients as introduced in Sections 4.3.2 and 4.4. The Earthquake catalogs are downloaded from the Data Sharing Infrastructure of the National Earthquake Data Center (http://data.earthquake.cn) The data are not freely downloadable. Their information and links are below.

FormalEq20090101T20210630 (Fig. 13):
https://data.earthquake.cn/datashare/report.shtml?PAGEID=datasourcelist&dt=40280d0453e414e40153e44861dd0003

域代码已更改

域代码已更改

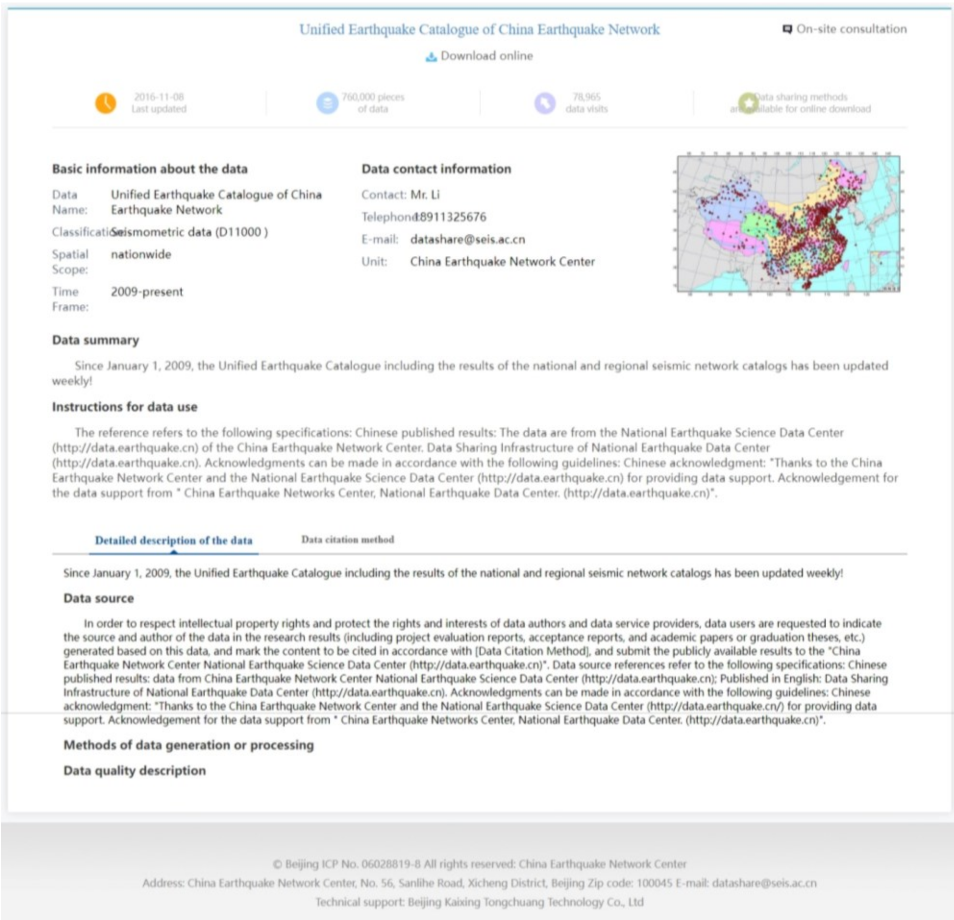


Figure 13: the translated English websites for FormalEq20090101T20210630.

CSNEq19700101T20081231 (Fig. 14):

https://data.earthquake.cn/datashare/report.shtml?PAGEID=datasourcelist&dt=40280d0453e414e40153e44861dd0002

域代码已更改

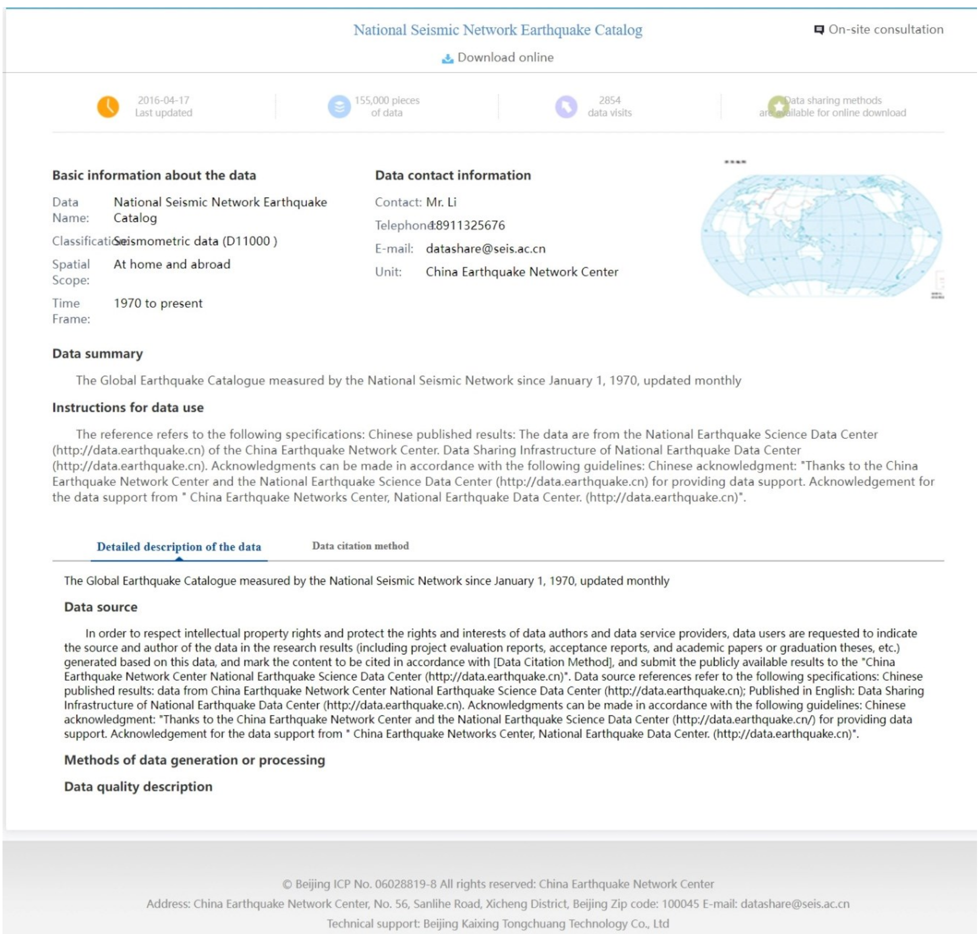
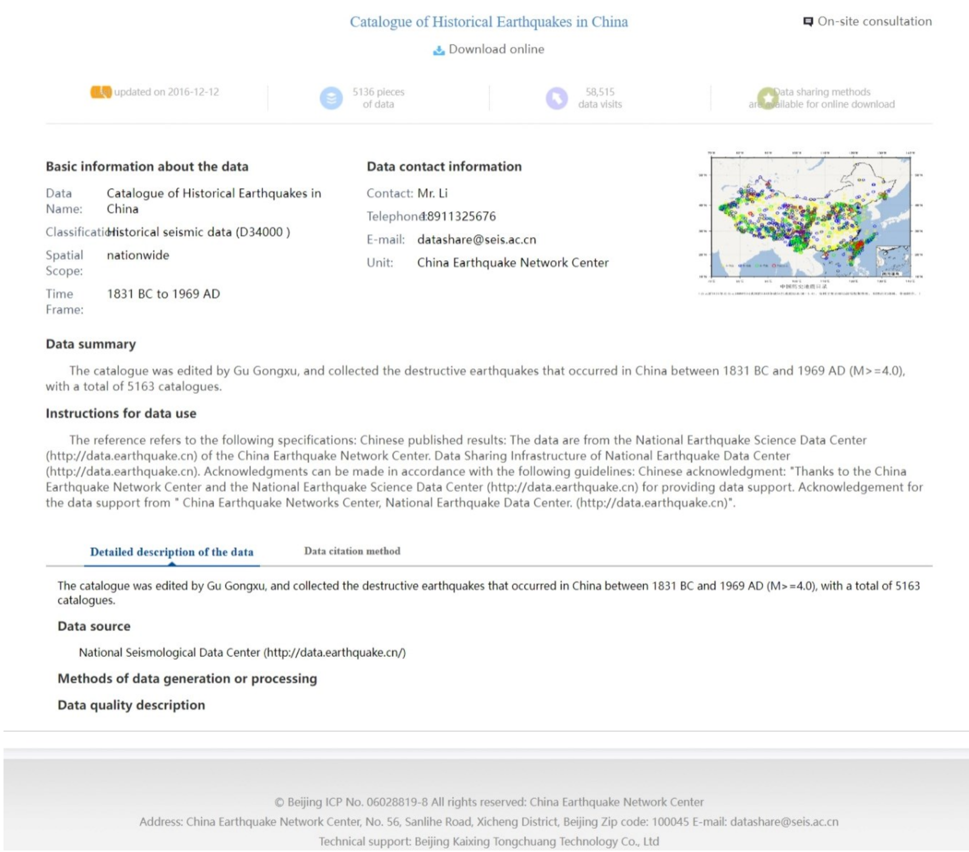


Figure 14: the translated English websites for CSNEq19700101T20081231.

HistoryEqT19691231 (Fig. 15):

https://data.earthquake.cn/datashare/report.shtml?PAGEID=datasourcelist&dt=8a85efd754e7d6910154e7d691810000


Catalogue of Historical Earthquakes in China

On-site consultation

Download online

updated on 2016-12-12 | 5136 pieces of data | 58,515 data visits | Data sharing methods are available for online download

Basic information about the data

Data Name: Catalogue of Historical Earthquakes in China

Classification: Historical seismic data (D34000)

Spatial Scope: nationwide

Time Frame: 1831 BC to 1969 AD

Data contact information

Contact: Mr. Li

Telephone: 18911325676

E-mail: datashare@seis.ac.cn

Unit: China Earthquake Network Center

Data summary

The catalogue was edited by Gu Gongxu, and collected the destructive earthquakes that occurred in China between 1831 BC and 1969 AD (M>=4.0), with a total of 5163 catalogues.

Instructions for data use

The reference refers to the following specifications: Chinese published results: The data are from the National Earthquake Science Data Center (http://data.earthquake.cn) of the China Earthquake Network Center. Data Sharing Infrastructure of National Earthquake Data Center (http://data.earthquake.cn). Acknowledgments can be made in accordance with the following guidelines: Chinese acknowledgment: "Thanks to the China Earthquake Network Center and the National Earthquake Science Data Center (http://data.earthquake.cn) for providing data support. Acknowledgement for the data support from " China Earthquake Networks Center, National Earthquake Data Center. (http://data.earthquake.cn)".

Detailed description of the data | Data citation method

The catalogue was edited by Gu Gongxu, and collected the destructive earthquakes that occurred in China between 1831 BC and 1969 AD (M>=4.0), with a total of 5163 catalogues.

Data source

National Seismological Data Center (http://data.earthquake.cn/)

Methods of data generation or processing

Data quality description

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Address: China Earthquake Network Center, No. 56, Sanlihe Road, Xicheng District, Beijing Zip code: 100045 E-mail: datashare@seis.ac.cn

Technical support: Beijing Kaixing Tongchuang Technology Co., Ltd

Figure 15: the translated English websites for HistoryEqT19691231.

7 Appendix A

Table A1: Cities list for updating the CAFD

No.	**City Name**	**Work Content**	**Reference Scale**
1	Beijing	UAFS	1:250000
2	Haikou	UAFS	1:250000
3	~~Huhehaote~~Hohhot	UAFS	1:250000
4	Kunming	UAFS	1:250000
5	~~Lasa~~Lhasa	UAFS	1:250000
6	Nanjing	UAFS	1:250000
7	Ningbo	UAFS	1:250000
8	Qingdao	UAFS	1:250000
9	Shanghai	UAFS	1:250000
10	Shenyang	UAFS	1:250000
11	Taiyuan	UAFS	1:250000
12	Xian	UAFS	1:250000
13	Changchun	UAFS	1:250000
14	Zhengzhou	UAFS	1:250000
15	~~Wulumuqi~~Urumqi	UAFS	1:250000
16	Xining	UAFS	1:250000
17	Guangzhou	UAFS	1:250000
18	Tianjin~~g~~	UAFS	1:250000
19	Lanzhou	UAFS	1:250000
20	Yinchuan	UAFS	1:250000
	UAFS: Urban Active Fault Survey		

Table A2: Faults list for updating the CAFD

~~**No.**~~	~~**Fault Name**~~	~~**Work Content**~~	~~**Reference Scale**~~
~~**1**~~	~~Xiaojiang fault~~	~~SM~~	~~1:50000~~
~~**2**~~	~~Junggar Basin south margin fault and Huoerguosi-Manasi-Tugulu fault~~	~~SM~~	~~1:50000~~
~~**3**~~	~~Laohushan fault and Maomaoshan fault~~	~~SM~~	~~1:50000~~
~~**4**~~	~~Tanlu fault zone~~	~~SM~~	~~1:50000~~
~~**5**~~	~~Xiangshan-Tianjingshan fault~~	~~SM~~	~~1:50000~~
~~**6**~~	~~Keketuohai-ertai fault~~	~~SM~~	~~1:50000~~
~~**7**~~	~~Honghe fault~~	~~SM~~	~~1:50000~~
~~**8**~~	~~Xianshuihe fault~~	~~SM~~	~~1:50000~~
~~**9**~~	~~Zemuhe fault~~	~~SM~~	~~1:50000~~
~~**10**~~	~~Anninghe fault~~	~~SM~~	~~1:50000~~
~~**11**~~	~~Langshan piedmont fault and Sertengshan Piedmont fault~~	~~SM~~	~~1:50000~~
~~**12**~~	~~Daqingshan piedmont fault~~	~~SM~~	~~1:50000~~
~~**13**~~	~~Xuanhua Basin north margin fault and Xuanhua Basin north margin fault~~	~~SM~~	~~1:50000~~
~~**14**~~	~~Huoshan fault~~	~~SM~~	~~1:50000~~
~~**15**~~	~~Taibai-Weishan piedmont fault~~	~~SM~~	~~1:50000~~

16	southern margin fault of Huaian basin (Western segment)	SM	1:50000
17	southern margin fault of Huaian basin (Eastern segment)	SM	1:50000
18	Heyang-Hancheng fault	SM	1:50000
19	Zhongtiaoshan piedmont fault	SM	1:50000
20	Northern margin fault of Emeitaidi	SM	1:50000
21	Luoyunshan piedmont fault	SM	1:50000
22	Taigu fault	SM	1:50000
23	northern foothill fault of the Hengshan mountains	SM	1:50000
24	Anqiu-Juxian fault	SM	1:50000
25	Yunongxi (Bawolong) fault	SM	1:50000
26	Litan fault and	SM	1:50000
27	eastern foothill fault of the Yulongxueshan Mountains	SM	1:50000
28	Weixi-Qiaohou-Weishan fault	SM	1:50000
29	Kusaihu-Maqu fault and Maqu-Heye fault	SM	1:50000
30	hanmuba-Lancang fault and Hanmuba fault	SM	1:50000
31	Shipping-Jianshui fault	SM	1:50000
32	Qujiang fault	SM	1:50000
33	Dayingjiang fault	SM	1:50000
34	Longlin-Ruili fault	SM	1:50000
35	Honghe fault (middle & Northern segment)	SM	1:50000
36	Anninghe fault	SM	1:50000
37	Xiaojiang fault South segment & North segment	SM	1:50000
38	Xianshuihe fault Moxi segment	SM	1:50000
39	Nantinghe fault	SM	1:50000
40	Xiaojiang fault	SM	1:50000
41	Yuanmou fault	SM	1:50000
42	Lijiang-Xiaojinhe fault	SM	1:50000
43	Heqing-Eryuan fault	SM	1:50000
44	Deqin-Zhongdian fault	SM	1:50000
45	Ninglang fault	SM	1:50000
46	Longpan-Qiaohou fault	SM	1:50000
47	Litang fault & Dewu fault & Labo fault & Xisasi fault	SM	1:50000
48	Daju fault	SM	1:50000
49	Chenghai fault	SM	1:50000
50	Ganzi-Yushu fault	SM	1:50000
51	Longriba fault	SM	1:50000
52	Tazang fault	SM	1:50000
53	Bailongjiang fault	SM	1:50000
54	Hanan-Qingshanwan-Mobali fault	SM	1:50000
55	Guanggaishan-Dieshan fault	SM	1:50000
56	Lintan-Dangchang fault	SM	1:50000
57	Lenglongling fault	SM	1:50000
58	Riyuanshan fault	SM	1:50000
59	Eastern foothill fault of the Liupanshan mountains	SM	1:50000
60	Guguan-Baoji fault	SM	1:50000
61	Southern margin fault of the Wuwei Basin	SM	1:50000
62	Minle-Damaying fault	SM	1:50000
63	eastern foothill fault of the Yumushan Mountains	SM	1:50000

64	Bodongmiao-Hongyazi fault	SM	1:50000
65	Yumen fault	SM	1:50000
66	Hanxia-Dahuanggou fault	SM	1:50000
67	Cangma fault	SM	1:50000
68	Eastern foothill fault of the Luoshan mountains	SM	1:50000
69	Guanguanling fault	SM	1:50000
70	TianqiaoGou-Huangyangchuan fault	SM	1:50000
71	Jintananshan fault	SM	1:50000
72	Altyn Tagh fault （Eastern segment）	SM	1:50000
73	Sertengshan Piedmont fault	SM	1:50000
74	Langshan piedmont fault	SM	1:50000
75	Yabulaishan fault	SM	1:50000
76	Jinshajiang fault	IFA	1:250000
77	Minjiang fault and Huya fault	IFA	1:50000
78	Yemahe Snow Mountain Fault Zone	SM	1:50000
79	Sanweishan fault	SM	1:50000
80	Keping fault	SM	1:50000
81	Kashi fault	SM	1:50000
82	Daliangshan fault	SM	1:50000
83	Liulengshan piedmont fault	SM	1:50000
84	Longmenshan Fault Zone (Middle segment)	SM	1:50000
85	South Tianshan fault zone	SM	1:50000
86	Southern margin fault zone of the Yuguang Basin	SM	1:50000
87	Jiaocheng fault	SM	1:50000
88	Xiadian fault	SM	1:50000
89	North margin fault of the Wulashan	SM	1:50000
90	Fukangnan fault	SM	1:50000
91	Huashan piedmont fault	SM	1:50000
92	Tomloan fault & Mingyaole fault & Kazikeaerte fault	SM	1:50000
93	Northern margin fault of the Daihai	SM	1:50000
94	Southern margin fault of the Chaiwobao Basin	SM	1:50000
95	Cixian-Daming fault	SM	1:50000
96	earthen foothill fault of the Helanshan mountains	SM	1:50000
97	Northern margin fault of the Ordos Basin	IFA	1:250000
98	Bayinhaote fault	SM	1:250000
99	Haixiu fault	IFA	1:250000
100	Southern margin fault of the Balikun Basin	SM	1:50000

SM: survey mapping. IFA: identification of fault activity.

No.	Project Name (Named by the Fault Name)	Work Content	Reference Scale
1	Altyn Tagh fault （Eastern segment）	SM	1:50000
2	Anninghe fault (Middle segment)	SM	1:50000
3	Anninghe fault (Northern segment)	SM	1:50000
4	Anninghe fault (Southern segment)	SM	1:50000
5	Anqiu-Juxian fault	SM	1:50000
6	Bailongjiang fault	SM	1:50000

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7	Bayinhaote fault zone	SM	1:250000
8	Bodongmiao-Hongyazi fault	SM	1:50000
9	Cangma fault	SM	1:50000
10	Chenghai fault	SM	1:50000
11	Cixian-Daming fault	SM	1:50000
12	Daju fault	SM	1:50000
13	Daliangshan fault	SM	1:50000
14	Daqingshan piedmont fault	SM	1:50000
15	Dayingjiang fault	SM	1:50000
16	Deqin-Zhongdian fault	SM	1:50000
17	earthen foothill fault of the Helanshan mountains	SM	1:50000
18	Eastern foothill fault of the Liupanshan mountains	SM	1:50000
19	Eastern foothill fault of the Luoshan mountains	SM	1:50000
20	eastern foothill fault of the Yulongxueshan Mountains	SM	1:50000
21	eastern foothill fault of the Yumushan Mountains	SM	1:50000
22	Fukangnan fault	SM	1:50000
23	Ganzi-Yushu fault	SM	1:50000
24	Guanggaishan-Dieshan fault	SM	1:50000
25	Guanguanling fault	SM	1:50000
26	Guguan-Baoji fault	SM	1:50000
27	Haixiu fault	IFA	1:250000
28	Hanan-Qingshanwan-Mobali fault	SM	1:50000
29	Hanmuba-Lancang fault and Hanmuba fault	SM	1:50000
30	Hanxia-Dahuanggou fault	SM	1:50000
31	Heqing-Eryuan fault	SM	1:50000
32	Heyang-Hancheng fault	SM	1:50000
33	Honghe fault (Northern segment)	SM	1:50000
34	Honghe fault (Middle segment)	SM	1:50000
35	Honghe fault (Southern segment)	SM	1:50000
36	Huashan piedmont fault	SM	1:50000
37	Huoshan fault	SM	1:50000
38	Jiaocheng fault zone	SM	1:50000
39	Jinshajiang fault	IFA	1:250000
40	Jintananshan fault	SM	1:50000
41	Junggar Basin south margin fault and Huoerguosi-Manasi-Tugulu fault	SM	1:50000
42	Keketuohai-ertai fault	SM	1:50000
43	Keping fault	SM	1:50000
44	Kusaihu-Maqu fault and Maqu-Heye fault	SM	1:50000

45	Langshan piedmont fault (Eastern segment)	SM	1:50000
46	Langshan piedmont fault (Western segment) and Sertengshan Piedmont fault	SM	1:50000
47	Laohushan fault and Maomaoshan fault	SM	1:50000
48	Lenglongling fault	SM	1:50000
49	Lijiang-Xiaojinhe fault	SM	1:50000
50	Lintan-Dangchang fault	SM	1:50000
51	Litang fault & Dewu fault & Labo fault & Xisasi fault	SM	1:50000
52	Litan-Yidun fault	SM	1:50000
53	Liulengshan piedmont fault	SM	1:50000
54	Longlin-Ruili fault	SM	1:50000
55	Longmenshan fault Zone (Middle segment)	SM	1:50000
56	Longpan-Qiaohou fault	SM	1:50000
57	Longriba fault	SM	1:50000
58	Luoyunshan piedmont fault	SM	1:50000
59	Minjiang fault and Huya fault	IFA	1:50000
60	Minle-Damaying fault	SM	1:50000
61	Nantinghe fault	SM	1:50000
62	Ninglang fault	SM	1:50000
63	North margin fault of the Xuanhua Basin and Southern margin fault of the Shenjin basin	SM	1:50000
64	northern foothill fault of the Hengshan mountains	SM	1:50000
65	Northern margin fault of Emeitaidi	SM	1:50000
66	Northern margin fault of Huaian basin	SM	1:50000
67	Northern margin fault of the Daihai	SM	1:50000
68	Northern margin fault of the Ordos Basin (Western segment)	IFA	1:250000
69	Qujiang fault	SM	1:50000
70	Riyuanshan fault	SM	1:50000
71	Sanweishan fault	SM	1:50000
72	Sertengshan Piedmont fault	SM	1:50000
73	Shiping-Jianshui fault	SM	1:50000
74	Southern margin fault of Huaian basin	SM	1:50000
75	Southern margin fault of the Balikun Basin	SM	1:50000
76	Southern margin fault of the Chaiwobao Basin	SM	1:50000
77	Southern margin fault of the Wuwei Basin	SM	1:50000
78	Southern margin fault zone of the Yuguang Basin	SM	1:50000
79	Taibai-Weishan piedmont fault	SM	1:50000
80	Taigu fault	SM	1:50000
81	Tanlu fault zone	SM	1:50000

82	Tazang fault	SM	1:50000
83	TianqiaoGou-Huangyangchuan fault	SM	1:50000
84	Tomloan fault & Kazikeaerte fault	SM	1:50000
85	Weixi-Qiaohou-Weishan fault	SM	1:50000
86	Wulashan piedmont fault	SM	1:50000
87	Xiadian fault	SM	1:50000
88	Xiangshan-Tianjingshan fault	SM	1:50000
89	Xianshuihe fault (Northern & Middle segment)	SM	1:50000
90	Xianshuihe fault (Moxi segment/Southern segment)	SM	1:50000
91	Xiaojiang fault (Middle segment)	SM	1:50000
92	Xiaojiang fault (Northern segment)	SM	1:50000
93	Xiaojiang fault (Southern segment)	SM	1:50000
94	Yabulai fault	SM	1:50000
95	Yemahe Snow Mountain Fault Zone	SM	1:50000
96	Yuanmou fault	SM	1:50000
97	Yumen fault	SM	1:50000
98	Yunongxi (Bawolong) fault	SM	1:50000
99	Zemuhe fault	SM	1:50000
100	Zhongtiaoshan piedmont fault	SM	1:50000

SM: survey mapping. IFA: identification of fault activity.

带格式表格

Table A3: Attributes of fault data.

Field name	Description
FractureZoneName_Ch	(in simplified Chinese) Fracture zone name. Only some
FractureZoneName_En	(in English) Fracture zone name.
FaultName_Ch	(in simplified Chinese) Fault name.
FaultName_En	(in English) Fault name.
FaultSegmentName_Ch	(in simplified Chinese) Fault segment name.
FaultSegmentName_En	(in English) Fault segment name.
FormerFaultName	(in simplified Chinese) Former name of fault.
Feature_Ch	(in simplified Chinese) Kinetic property and detectability of the fault segment.
Feature_En	(in English) Kinetic property and detectability of the fault segment.
Age	(in English abbreviations) The active age of the fault segment.

Table A4: Attributes of HistoryEqT19691231.

Field Name	Description
time_beiji	The origin date and origin time of the earthquake (GMT +8).
lon	Epicentral longitude of the earthquake.
lat	Epicentral latitude of the earthquake.
dep	The focal depth of the earthquake is in km.
magnitude	Magnitude (M).
intensity	(Macro) epicentral intensity.

Table A5: Attributes of CSNEq19700101T20081231.

Field Name	Description
time_gmt_	The origin date and origin time of the earthquake (GMT).
lon	Epicentral longitude of the earthquake.
lat	Epicentral latitude of the earthquake.
dep_km_	The focal depth of the earthquake is in km.
ms	Surface wave magnitude.
ms7	Surface wave magnitude was computed from records of the Chinese-made long-period seismograph of type 763 (Cheng et al., 2017).
ml	Local magnitude.
mb	Body wave magnitude, measured by short-period body wave recording (mb).
mb_1	Body wave magnitude, measured by medium-period body wave recording (mB).

Table A6: Attributes of FormalEq20090101T20210630.

Field Name	Description
Date	The origin date and origin time of the earthquake (GMT +8).
lon	Epicentral longitude of the earthquake.
lat	Epicentral latitude of the earthquake.
dep_km_	The focal depth of the earthquake in km.
magnitudet	Magnitude type.
magnitude	Magnitude.

Author contributions

带格式的: 非突出显示

Conceptualization, XX, and XW; Data curation, GY, XW, GC, JR, KL, and CX; Formal analysis, KD, XX, XW, GY; Funding acquisition, XX, GY, and XW; Investigation, XX, XW, GY, GC, XY, HY, and XH; Methodology, GY, XW, KD, GC, JR, KL, and CX; Project administration, XX, GY, and XW; Software, KD and XW; Supervision, XX and GY; Validation, XX and XW; Writing, XW and XX. All authors have read and agreed to the published version of the manuscript.

Competing interests

The authors declare that they have no conflict of interest.

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