doi: 10.12029/gc2019Z204

论文引用格式：张茂省，王益民，张戈，董英，孙萍萍，贾俊. 2019. 干扰环境下城市地下空间组合探测与全要素数据集 [J].中国地质，46(S2):30−49.

数据集引用格式：张茂省; 王益民; 张戈; 董英; 孙萍萍; 贾俊. 干扰环境下城市地下空间组合探测与全要素数据集 (V1).中国地质调查局西安地质调查中心;陕西省水资源与环境工程技术研究中心 [创建机构]，2013. 全国地质资料馆 [传播机构]，2019-12-30.10.23650/data.D.2019.P14; http://dcc.cgs.gov.cn/data/doi/10.23650/data.D.2019.P14

收稿日期：2019-10-23
改回日期：2019-11-08

基金项目：中国地质调查局地质调查项目“陕西省重要城镇地质灾害风险评估、关中-天水经济区综合地质调查、西安多要素城市地质调查、延安革命老区综合地质调查”（DD20160261、DD20189220、DD20189270）。

干扰环境下城市地下空间组合探测与全要素数据集

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摘要：地下空间利用已成为解决城市发展空间问题的主要途径，地下空间精准探测是地下空间资源开发利用的基础，但城市强干扰环境下地下空间探测的原理、方法组合、采集的要素及数据应用等目前尚为难题。本数据集依托中国地质调查局陕西省重要城镇地质灾害风险评估（2013—2016）、关中-天水经济区综合地质调查（2016—2018）、西安多要素城市地质调查（2018—2021）、延安革命老区综合地质调查（2018—2021） 4 个项目，面向岩土体质量评价和城市地下空间资源评价与开发利用的需要，在常规物探、钻探和实验测试基础上，引入了随钻监测技术，开展了 13 个参数的测井，形成了地下空间组合探测方法，获取了岩土体质量和城市地下空间评价所需的全要素数据。本数据集分别来自陕西省秦巴山地山阳县城区、关中盆地西安市城区和黄土高原延安市城区，数据包含工程地质钻探、实验测试、多参数测井、随钻监测和地面物探 5 种数据类型，其中工程地质钻孔 144 个，实验测试样品 672 个，物探测井 13 类参数 111 个孔，随钻监测 36 个孔，地面物探 4 类方法 5 条剖面，共计 968 组数据，3 664 个文件，格式包含 jpg，xls，doc，mpj，dwg。该数据集可用于岩土体质量评价、城市三维地质全要素建模、地下空间资源评价、岩土体质量与物性参数耦合关系研究，以及城市地质科学研究。

关键词：钻探；随钻监测；地面物探；多参数测井；地下空间；城市地质调查工程；西安

数据服务系统网址：http://dcc.cgs.gov.cn

1 引言

随着中国城市化进程的不断加快，越来越多的城市面临着空间资源紧缺、环境恶化等问题（钱七虎，1998），对城市地质工作提出了更高的要求（张茂省等，2014）。地下空间为城市的基础设施、生活服务的重要空间，是保证现代城市可持续发展的必要条

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件（Bobylev N，2009；Broere W，2016；张茂省等，2018；王化齐等，2019）。地下空间开发利用已成为解决城市发展空间问题的主要途径。

不同城市的地下空间开发利用需要考虑多种地质环境条件。山地丘陵区城市的地形地貌条件导致地表空间严重短缺，然而其地质环境条件有利于地下空间的开发利用（张茂省等，2019；杨文采等，2019）；历史文化名城的地下空间开发要考虑地下历史遗迹的保护（乔永康等，2017）；存在地面沉降、地裂缝、活动构造、黄土湿陷、砂土液化、地质灾害等地质环境问题的城市，需要查明这些限制地下空间开发利用的环境地质条件（张茂省等，2013；田中英等，2019；张珊珊等，2019；周圆心等，2019；戚帮申等，2019）。

地下空间及地质环境条件的精准探测是地下空间资源评价和开发利用的基础（王亚辉等，2019），为城市三维地质建模提供数据支撑（何静等，2019）。由于城市强干扰的物理场环境、复杂的地质环境条件和既有建筑物影响，城市地下空间探测的理论方法还不成熟（陈伟，2006；赵镨等，2017），在城市强干扰环境下，地下空间探测的地质调查技术方法组合及其获取的数据资料不能完全满足城市地下空间资源评价和开发利用规划的需求。

2013—2016 年在实施中国地质调查局“陕西省重要城镇地质灾害风险评估（山阳县）”过程中，为了科学评价岩土体质量，探测软弱结构面，给地质灾害风险评估提供判识依据，项目组与香港大学岳中琦教授合作，引入了其研发的随钻监测技术（Yue ZQ et al.，2004；岳中琦，2014），获取了第一批随钻监测数据。

2017 年在实施中国地质调查局“关中-天水经济区综合地质调查”项目期间（2016—2018），以服务于面向盾构施工法的岩土体质量评价、地下空间资源评价、三维地质建模为目的，在大西安的西咸新区和灞桥区分别实施了地下空间组合探测方法试验，尝试了第四纪松散堆积层区的随钻监测，与西北大学谷天峰副教授合作改进了随钻监测仪器，并选择 13 个参数进行了物探测井，成功获取了 2 个试验孔的钻探、随钻监测和 13 个参数的测井数据，形成了地下空间组合探测方法。

2018 年启动了“西安多要素城市地质调查（2018—2021）”和“延安革命老区综合地质调查（2018—2021）”二级项目，面向岩土体质量评价和城市地下空间资源评价与开发利用的需要，在常规物探、钻探和实验测试基础上，全面开展了综合物探、随钻监测和 13 个参数的测井工作，获取了岩土体质量和城市地下空间评价所需的全要素数据。

本数据集资料采自陕西省秦巴山地山阳县城区、关中盆地西安市城区和黄土高原延安市城区，数据包含工程地质钻探、实验测试、多参数测井、随钻监测和地面物探数据 5 类，其中工程地质钻孔 144 个，实验测试样品 672 个，物探测井 13 类参数 111 个孔，随钻监测 36 个孔，地面物探 4 类方法 5 条剖面，共计 968 组数据，3 664 个文件，格式包含 jpg，xls，doc，mpj，dwg。数据集的元数据简表如表 1 所示。

2 数据采集和处理方法

本数据集工作区域分别是陕西省秦巴山地山阳县城区、关中盆地西安市城区和黄土高原延安市城区，工区地理位置及地势如图 1 所示。

2.1 工程地质钻探

工程地质钻探的目标是揭示地层结构及其工程地质性质，建立三维地质结构模型。

表 1 数据库 (集) 元数据简表

条目	描述
数据库（集）名称	干扰环境下城市地下空间组合探测与全要素数据集
数据库（集）作者	张茂省，中国地质调查局西安地质调查中心，陕西省水资源与环境工程技术研究中心 王益民，中国地质调查局西安地质调查中心，陕西省水资源与环境工程技术研究中心 张 戈，中国地质调查局西安地质调查中心，陕西省水资源与环境工程技术研究中心 董 英，中国地质调查局西安地质调查中心，陕西省水资源与环境工程技术研究中心 孙萍萍，中国地质调查局西安地质调查中心，陕西省水资源与环境工程技术研究中心 贾 俊，中国地质调查局西安地质调查中心，陕西省水资源与环境工程技术研究中心
数据时间范围	2013—2018年
地理区域	西安市，东经107°24′ ~ 109°30′，北纬33°24′ ~ 34°24′ 延安市，东经109°22′ ~ 109°37′，北纬36°27′ ~ 36°40′ 山阳县，东经109°50′10″ ~ 109°56′57″，北纬33°30′27″ ~ 33°33′05″
数据格式	.jpg，.xls，.doc，.mpj，.dwg
数据量	1.19 GB
数据服务系统网址	http://dcc.cgs.gov.cn
基金项目	中国地质调查局地质调查项目 “陕西省重要城镇地质灾害风险评估、关中-天水经济区综合地质调查、西安多要素城市地质调查、延安革命老区综合地质调查”（DD20160261、DD20189220、DD20189270）
语种	中文
数据库（集）组成	钻探数据包括：钻孔编号、钻孔地理位置、钻孔坐标、孔口高程、钻机类别、施工方法、施工日期、钻孔深度、地层岩性描述、分层序号、分层厚度、取样深度 测井数据包括：测量日期、测量深度、自然伽玛、自然电位、密度、声波时差、双侧向电阻率、极化率、磁化率、伽玛能谱、井温、井径、井斜 随钻监测数据包括：测量日期、钻进回次、加杆长度、钻孔深度、油缸位移、钻杆转速、油压、扭压 实验测试数据包括：土样测试数据为样品编号、取样深度、含水率、天然密度、粘聚力、内摩擦角、自重湿陷系数、比表面积，岩芯测试数据为样品编号、取样深度、声波速度、单轴抗压强度 地面物探数据包括：测量日期、探测方法、排列装置、测量点数、测线长度、采样间隔

本数据集共采集工程地质勘探钻孔 144 个。其中，西安工区实施了 104 个工程地质勘探钻孔（图 2），延安工区实施了 32 个钻孔（图 3），山阳工区实施了 8 个钻孔（图 4）。表 2 ~ 表 4 为钻孔基本情况信息。

2.2 多参数测井

测井数据包含西安和延安 2 个文件夹，每个文件夹包含单孔数据、对比图、等值线图和总结报告。西安工区完成了 98 个钻孔的全要素测井，延安工区完成了 13 个钻孔的全要素测井。测井参数包括自然伽玛、自然电位、密度、声波时差、双侧向电阻率、极化率、磁化率、伽玛能谱、井温、井径、井斜。测井采用 KH-2 数字测井仪，测量速度 6 ~ 10 m/min，每种方法的数据采集符合相应的技术要求。根据统计可以得到地层的测

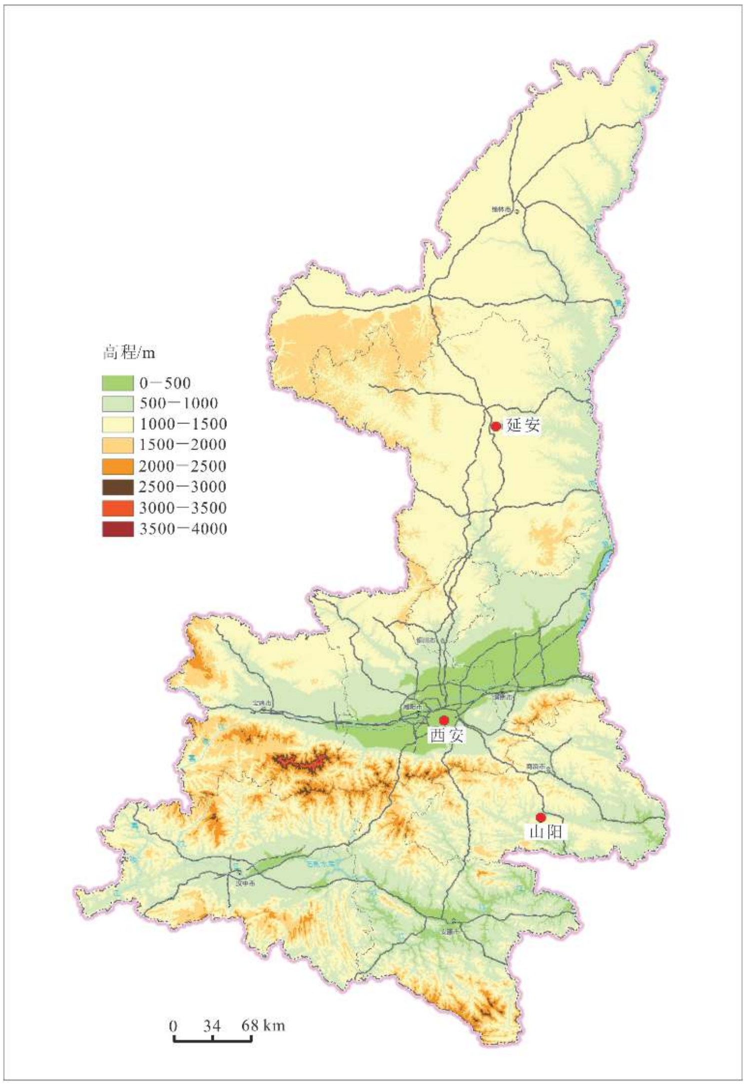

图 1　西安-延安-山阳工区地势图

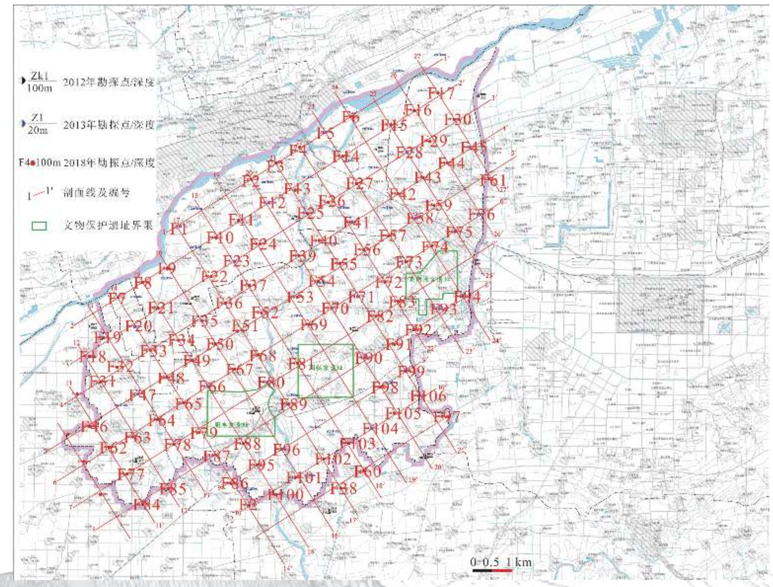

图 2　西安市工程地质钻孔分布图

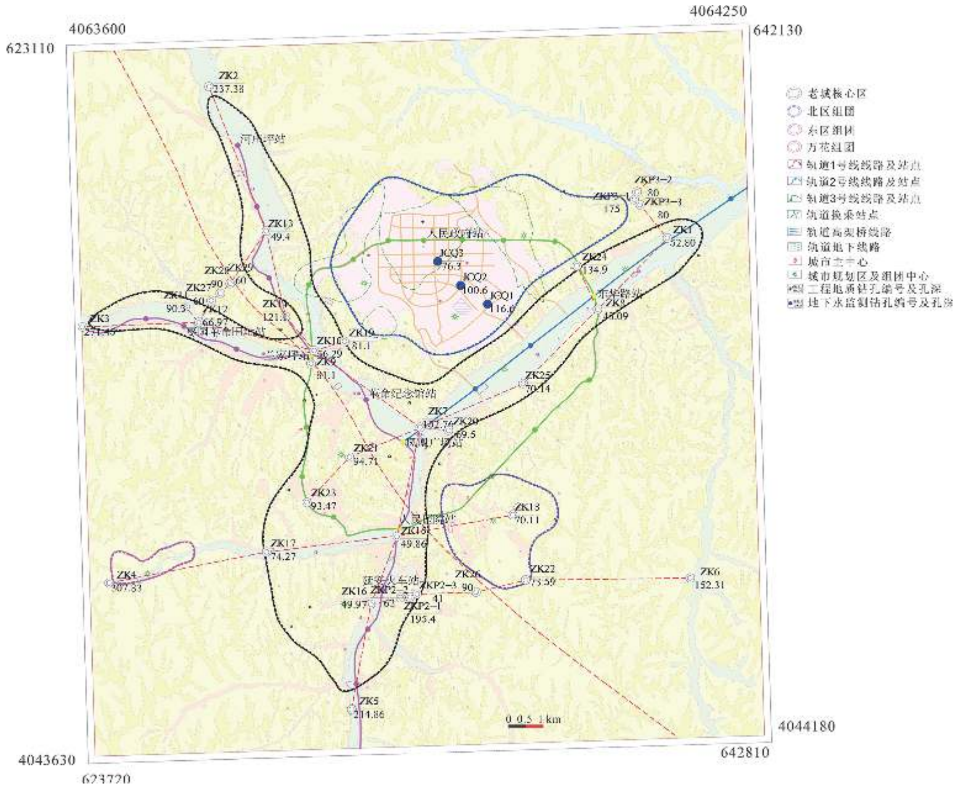

图 3　延安市工程地质钻孔分布图

图 4　山阳县工程地质钻孔分布图

井参数特征。根据声波速度和密度，可以计算地层的力学参数。根据所有单孔的数据，可以绘制工区测井参数的等值线图。

2.3　随钻监测

随钻监测数据包含西安、延安、山阳 3 个文件夹，以及随钻监测系统使用说明、随钻监测数据分析流程文件。每个文件夹包含初始数据、随钻监测记录表、数据分析过程

表 2　西安市工程地质钻孔基本情况

钻孔编号	钻孔深度/m	编录岩性	测井	随钻监测	实验测试
白鹿原	200.00	黄土、粉质黏土、砂砾石层		有	
机场	200.00	黄土、粉质黏土、细砂、砂砾石层		有	
F1	150.00	细砂、中砂、粉质黏土、砂砾石层	有		
F2	100.00	黄土状土、粉质黏土、中砂、粗砂			
F3	100.00	黄土状土、粉质黏土、细砂、中砂			
F4	100.00	黄土状土、粉质黏土、细砂、中砂、砂砾石层	有		
F5	100.00	黄土状土、中砂、砂砾石层	有		
F6	100.00	黄土状土、粉质黏土、细砂、粗砂	有		
F7	100.20	黄土状土、粉质黏土、粗砂、砾砂			
F8	100.00	黄土状土、粉质黏土、细砂、中砂			
F9	100.00	粉质黏土、细砂、中砂、砂砾石层	有		
F10	100.00	黄土状土、粉质黏土、细砂、中砂、砾砂	有		土样
F11	100.00	黄土状土、粉质黏土、细砂、中砂、砾砂、砂砾石层	有		
F12	150.00	黄土状土、粉质黏土、细砂、中砂、粗砂、砂砾石层	有		土样
F13	100.00	粉质黏土、细砂、中砂、粗砂、砾砂、砂砾石层、	有		
F14	100.00	粉质黏土、细砂、中砂、粗砂、砾砂	有	有	土样
F15	100.00	粉质黏土、细砂、中砂、粗砂、	有		
F16	100.00	粉质黏土、细砂、中砂、粗砂、	有	有	土样
F17	100.00	粉质黏土、细砂、中砂、粗砂、	有		土样
F18	100.10	粉质黏土、细砂、中砂、粗砂、砾砂、砂砾石层	有		
F19	100.00	中砂、砾砂、砂砾石层	有	有	土样
F20	150.00	粉质黏土、细砂、中砂、砾砂、砂砾石层	有	有	土样
F21	100.00	粉质黏土、细砂、中砂、粗砂、砾砂、砂砾石层	有		土样
F22	100.00	黄土状土、粉质黏土、细砂、中砂、粗砂、砾砂	有		土样
F23	150.00	粉质黏土、细砂、中砂、粗砂、砾砂、砂砾石层	有		土样
F24	100.00	黄土状土、粉质黏土、细砂、中砂	有		
F25	100.00	粉质黏土、细砂、中砂、粗砂、砾砂	有		土样
F26	100.00	粉质黏土、细砂、中砂、砂砾石层	有		土样
F27	100.00	粉质黏土、中砂、粗砂	有	有	土样
F28	150.00	粉质黏土、细砂、粗砂	有		土样
F29	100.00	粉质黏土、细砂、粗砂	有		土样
F30	100.00	粉质黏土、细砂、粗砂	有		
F31	100.00	粉质黏土、细砂、中砂、粗砂、砾砂	有		土样
F32	100.00	粉质黏土、细砂、中砂、粗砂、砾砂、砂砾石层	有		土样
F33	100.00	粉质黏土、细砂、中砂、砾砂、砂砾石层			土样
F34	100.00	粉质黏土、细砂、中砂、砾砂	有		土样
F35	150.00	黄土状土、粉质黏土、细砂、中砂、粗砂、砾砂	有		土样
F36	100.00	粉质黏土、细砂、中砂、粗砂、砂砾石层	有		土样
F37	100.00	粉质黏土、细砂、中砂、粗砂	有		土样
F38	100.00	黄土状土、粉质黏土、细砂、中砂、粗砂	有		
F39	100.00	粉质黏土、细砂、中砂、粗砂、砂砾石层	有		土样

续表 2

钻孔编号	钻孔深度/m	编录岩性	测井	随钻监测	实验测试
F40	100.20	粉质黏土、细砂、中砂、砾砂	有		
F41	150.00	粉质黏土、细砂、中砂、粗砂、	有	有	土样
F42	100.00	细砂、中砂、粗砂、	有		土样
F43	100.00	粉质黏土、细砂、中砂、粗砂、	有	有	
F44	100.00	粉质黏土、细砂、中砂、粗砂、砾砂、砂砾石层	有		土样
F45	150.00	粉质黏土、细砂、中砂、粗砂、	有	有	土样
F46	100.00	粉质黏土、细砂、中砂、粗砂、砾砂、砂砾石层	有		土样
F47	150.00	黄土状土、粉质黏土、细砂、中砂、砾砂、砂砾石层	有	有	土样
F48	100.00	黄土状土、粉质黏土、细砂、中砂、粗砂、砾砂、砂砾石层	有		
F49	100.00	粉质黏土、细砂、中砂、粗砂、砾砂	有		土样
F50	100.00	粉质黏土、细砂、中砂、粗砂、砾砂、砂砾石层	有		土样
F51	100.00	粉质黏土、细砂、中砂、砂砾石层	有		土样
F52	100.00	细砂、中砂、砾砂	有		土样
F53	100.00	粉质黏土、细砂、中砂、砾砂	有		土样
F54	100.00	粉质黏土、细砂、中砂、粗砂、砾砂	有		土样
F55	100.00	粉质黏土、细砂、中砂、粗砂、砾砂	有		土样
F56	100.00	粉质黏土、细砂、中砂、砾砂	有		
F57	100.00	粉质黏土、细砂、中砂、粗砂	有	有	土样
F58	150.00	粉质黏土、细砂、中砂、粗砂、砂砾石层	有	有	土样
F59	100.00	粉质黏土、细砂、中砂、砾砂	有		土样
F60	100.50	黄土状土、粉质黏土、细砂、中砂	有		
F61	100.00	粉质黏土、细砂、中砂、砾砂	有		土样
F62	100.40	黄土状土、粉质黏土、中砂	有		
F63	100.00	粉质黏土、中砂、砾砂	有		
F64	100.00	粉质黏土、细砂、中砂、砂砾石层	有	有	土样
F66	150.00	黄土状土、粉质黏土、细砂、中砂、砂砾石层	有	有	
F67	100.10	粉质黏土、细砂、中砂、粗砂、砾砂	有		
F68	100.00	粉质黏土、细砂、中砂、砂砾石层	有		土样
F69	100.00	粉质黏土、细砂、中砂	有		土样
F70	100.00	粉质黏土、细砂、中砂、粗砂	有	有	土样
F71	150.00	粉质黏土、细砂、粗砂、砾砂	有	有	土样
F72	100.00	粉质黏土、细砂、中砂	有	有	土样
F73	100.00	粉质黏土、细砂、中砂	有		土样
F74	100.00	粉质黏土、细砂、中砂、粗砂	有		土样
F75	100.00	粉质黏土、细砂、中砂	有		土样
F76	150.00	粉质黏土、细砂、中砂、粗砂、砾砂	有		土样
F77	100.20	粉质黏土、细砂、中砂、粗砂	有		
F78	100.10	黄土状土、粉质黏土、中砂、粗砂、砾砂			
F79	100.10	粉质黏土、细砂、中砂、粗砂	有		
F80	150.10	粉质黏土、细砂、中砂、砾砂	有		
F81	100.50	粉质黏土、细砂、中砂、粗砂、砾砂	有		
F82	100.30	粉质黏土、细砂、中砂	有		

续表 2

钻孔编号	钻孔深度/m	编录岩性	测井	随钻监测	实验测试
F83	100.00	粉质黏土、细砂、中砂、砾砂、砂砾石层	有		土样
F84	100.50	黄土状土、粉质黏土、细砂、中砂	有		
F85	100.10	黄土状土、粉质黏土、中砂、砾砂			
F86	100.20	粉质黏土、细砂、中砂	有		
F87	150.00	粉质黏土、细砂、中砂、砾砂、砂砾石层	有		土样
F88	100.20	黄土状土、粉质黏土、中砂、粗砂、砾砂	有		
F89	100.20	粉质黏土、细砂、中砂、粗砂	有		
F90	150.00	粉质黏土、细砂、中砂、粗砂	有	有	土样
F91	100.00	粉质黏土、细砂、中砂	有		土样
F92	100.00	粉质黏土、中砂	有	有	土样
F93	150.40	粉质黏土、细砂、中砂、粗砂、砂砾石层	有		
F95	100.20	粉质黏土、细砂、中砂	有		
F96	150.30	粉质黏土、细砂、中砂、粗砂	有		
F97	100.50	黄土状土、粉质黏土、中砂、粗砂	有		
F98	100.50	粉质黏土、细砂、中砂、粗砂	有		
F99	100.10	粉质黏土、细砂、中砂、粗砂	有		
F100	100.10	粉质黏土、中砂、粗砂	有		
F101	100.00	粉质黏土、细砂、中砂	有		土样
F102	100.00	粉质黏土、细砂、中砂	有		
F103	100.20	粉质黏土、细砂、中砂	有		
F104	150.00	粉质黏土、细砂、中砂	有	有	土样
F105	100.40	粉质黏土、细砂、中砂、粗砂	有	有	
F106	100.00	黄土状土、粉质黏土、细砂、中砂、粗砂	有		土样

和结果图。随钻监测数据在 excel 处理，分析过程保存为 word 文件，处理后的数据在 surfer 软件成图。西安随钻监测数据包含 22 个钻孔，延安随钻监测数据包含 6 个钻孔，山阳随钻监测数据包含 8 个钻孔。随钻监测采用香港大学和自主研制的随钻监测系统，包括位移传感器、转速传感器、油压传感器、扭压传感器、数据采集器，采样间隔 1 ~ 2 s。随钻监测的数据处理是从初始数据提取表示钻进过程的有效数据，并计算进尺、钻进时间和钻进速度。表 5 为从随钻监测初始数据提取有效数据的条件。

根据提取的有效数据，可以得到钻进时间-进尺曲线、钻进速度-进尺曲线、转速-进尺曲线、油压-进尺曲线、扭压-进尺曲线。

2.4 实验测试

实验测试数据保存为 excel 格式，共 3 个文件。实验测试数据包括：土样测试数据为样品编号、取样深度、含水率、天然密度、粘聚力、内摩擦角、自重湿陷系数、比表面积，岩芯测试数据为样品编号、取样深度、声波速度、单轴抗压强度。

2.5 地面物探

在西安开展了地下空间精细化探测试验（表 6）。城市环境干扰因素多，电磁干扰、震动干扰强烈。高密度电法和微动台阵的探测深度较大，而探地雷达的分辨率较

高，因此将这些方法联合，在同一区域实施探测，分析每种方法的探测效果。图 5 是西安城市地下空间探测示意图。微动台阵采用 WD-1 智能微动勘探仪，嵌套三角形的台阵方式，最小三角形台站距离 6 ~ 10 m，采样间隔 10 ms。高密度电法采用 EDJD-1 多功能直流电法仪，温纳装置，电极间距 5 m。地质雷达采用 SIR-4000 地质雷达，100 MHz 和 200 MHz 天线，采样间距 1 m。浅层地震采用 SE2404NT 多道分布式工程地震仪和 60 Hz 检波器，多次覆盖单边激发反射波勘探，锤击震源，道间距 4 m，覆盖次数 8 次，采样间隔 0.5 ms，记录长度 512 ms。

表 3　延安市工程地质钻孔基本情况

钻孔编号	钻孔深度/m	编录岩性	测井	随钻监测	实验测试
ZK01	52.30	粉质黏土、砂砾石层、细砂岩、泥岩			
ZK02	192.86	粉质黏土、砂砾石层、细砂岩、泥岩、粗砂岩	有	有	岩芯
ZK03	272.68	粉质黏土、砂砾石层、细砂岩、泥岩、粗砂岩	有	有	岩芯
ZK04	293.00	细砂岩、泥岩、粗砂岩	有	有	
ZK05	214.00	细砂岩、泥岩、粗砂岩	有		岩芯
ZK06	139.00	砂砾石层、细砂岩、泥岩	有	有	岩芯
ZK07	202.00	细砂岩、泥岩、粗砂岩	有	有	
ZK08	56.80	粉质黏土、砂砾石层、细砂岩、泥岩			
ZK09	151.00	黄土、细砂岩、泥岩、粗砂岩	有		
ZK10	119.50	细砂岩、泥岩、粗砂岩			
ZK12	102.00	粉质黏土、砂砾石层、细砂岩、泥岩、粗砂岩		有	
ZK13	92.00	粉质黏土、细砂、砂砾石层、细砂岩、泥岩、粗砂岩			岩芯
ZK14	90.00	黄土、红黏土、细砂岩、泥岩	有		土样
ZK15	99.00	细砂岩、泥岩、粗砂岩	有		岩芯
ZK16	130.00	细砂岩、泥岩、粗砂岩			岩芯
ZK17	174.00	细砂岩、泥岩、粗砂岩	有		岩芯
ZK18	92.00	细砂岩、泥岩、粗砂岩			
ZK19	120.00	黄土、红黏土、粗砂岩		有	
ZK21	118.00	细砂岩、泥岩、粗砂岩	有		
ZK22	98.00	黄土、细砂岩、泥岩、粗砂岩	有		
ZK23	173.00	红黏土、细砂岩、泥岩、粗砂岩	有		
ZK24	104.00	黄土			土样
ZK25	89.00	黄土、红黏土			
ZK26	64.00	黄土、红黏土、细砂岩、泥岩、			土样
ZK27	123.00	黄土			土样
ZK28	108.00	黄土、红黏土、细砂岩、泥岩、			土样
ZKP2-1	126.80	黄土、红黏土、细砂岩、泥岩、			
ZKP2-2	75.40	红黏土、细砂岩、泥岩			
ZKP2-3	50.00	黄土、细砂岩、泥岩、粗砂岩			
ZKP3-1	117.00	黄土、红黏土			土样
ZKP3-2	110.00	黄土、红黏土、细砂岩、泥岩、			土样
ZKP3-3	131.50	黄土、红黏土			土样

表 4　山阳县工程地质钻孔基本情况

钻孔编号	钻孔深度/m	编录岩性	测井	随钻监测	实验测试
山阳中学ZK1	20.00	黏土、粗砂、砂砾石层		有	
山阳中学ZK3	20.00	黏土、粗砂、砂砾石层		有	
山阳中学ZK4	20.00	粉质黏土、黏土、钙质结核		有	
山阳中学ZK5	20.00	黏土、中砂、粗砂、砂砾石层		有	
桥儿沟ZK2	20.00	坡积层、千枚岩		有	
桥儿沟ZK3	34.00	滑坡堆积物、千枚岩		有	
桥儿沟ZK4	20.00	坡积层、千枚岩		有	
桥儿沟ZK5	20.00	坡积层、千枚岩		有	

表 5　随钻监测提取钻进过程有效数据的判断条件

钻机状态		位移传感器C	转速传感器R	油压传感器P
钻进过程	加压钻进	$C2\text{-}C1<a$	$R>0$	$P1>P2$
	不加压钻进	$C2\text{-}C1=0$	$R>0$	$P1=P2=0$
其他过程	空钻	$C2\text{-}C1>$a	$R>0$	$P1>P2$
	下钻杆、上钻杆	$C2\text{-}C1=0$	$R=0$	$P1<P2$

注：$P1$是上油压，$P2$是下油压，a是根据随钻监测数据和钻孔记录确定的数值，在岩石和土中钻进的a值不同。

表 6　西安城市地下空间探测基本情况

序号	工作方法	测量日期	工作量	采样间隔/m
1	多参数综合测井	9月11～21日	200 m	0.05
2	微动台阵	10月11～14日	16点	100
3	高密度电法	10月19～22日	2.01 km	7
4	浅层地震	10月14～28日	1.8 km	4
5	地质雷达	10月23～26日	2.8 km	1
6	高密度电法	11月8～11日	2.04 km	5

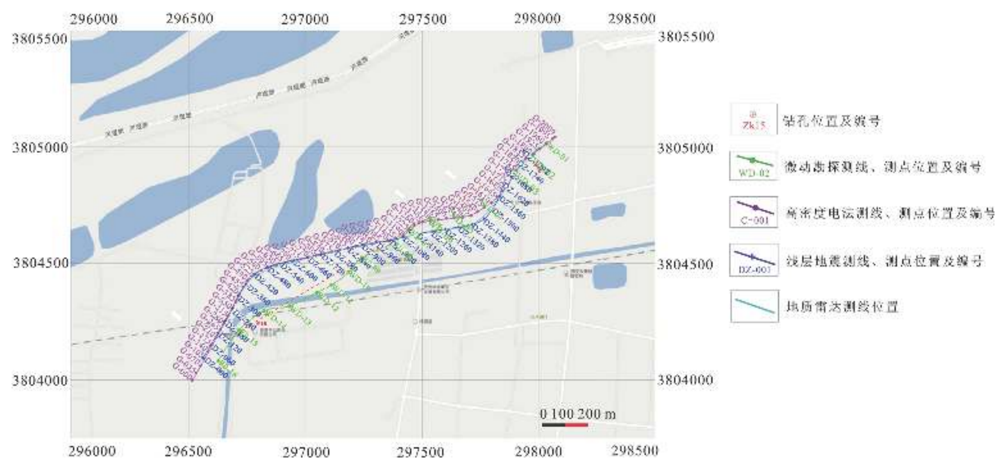

图 5　西安城市地下空间精细化探测示意图

3 数据样本描述

3.1 工程地质钻探

工程地质钻探获取的数据信息包括钻孔深度、地层岩芯等，经过人工编录得到钻孔综合地层柱状图，然后数字化。表 7 为钻孔数据名称及文件格式。

图 6 是延安 ZK10 综合地层柱状图。该柱状图包含了延安组、富县组和瓦窑堡组砂岩、泥岩，体现了延安工区沉积地层的结构。

表 7　工程地质钻孔文件格式

数据名称	文件格式
西安钻孔地层柱状图	dwg格式（CAD文件）
延安钻孔地层柱状图	mpj格式（MapGIS文件）

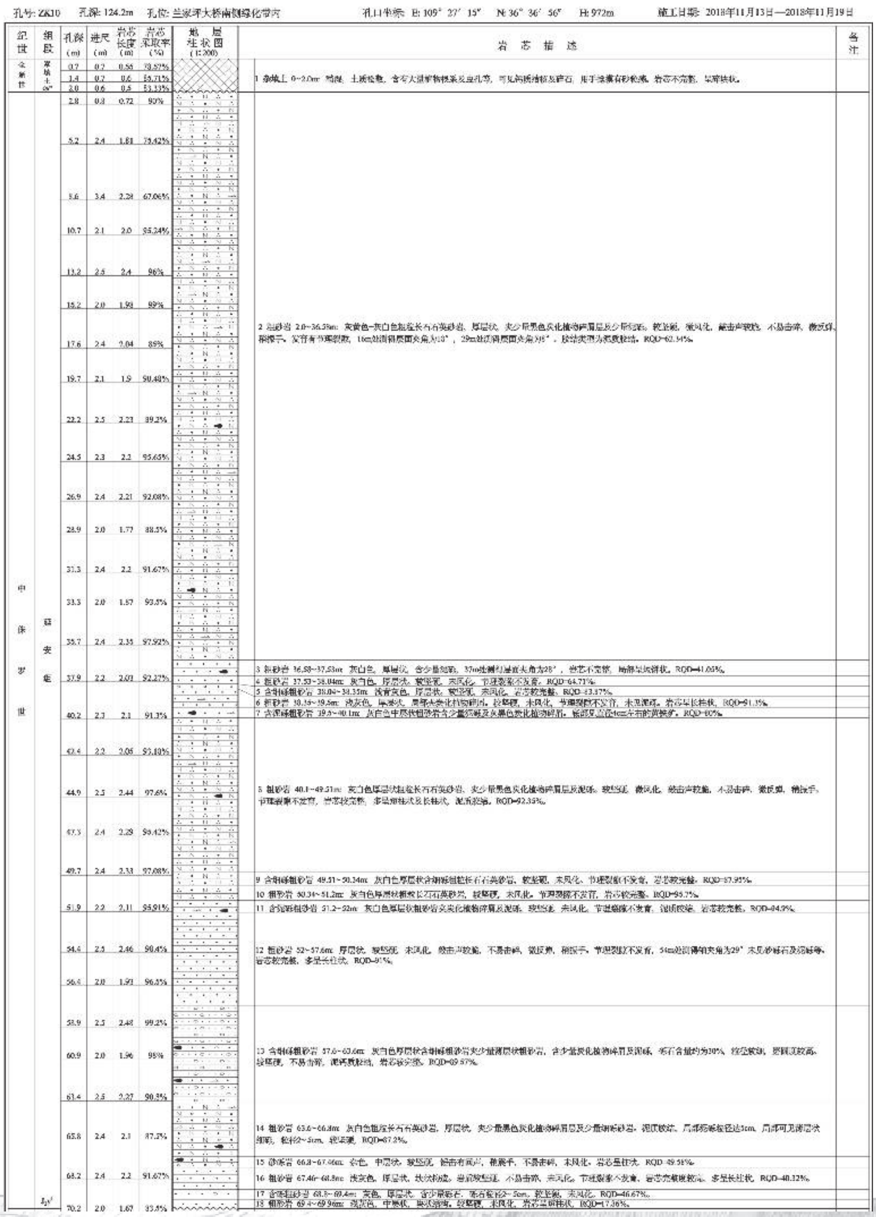

图 6　ZK10 岩芯编录

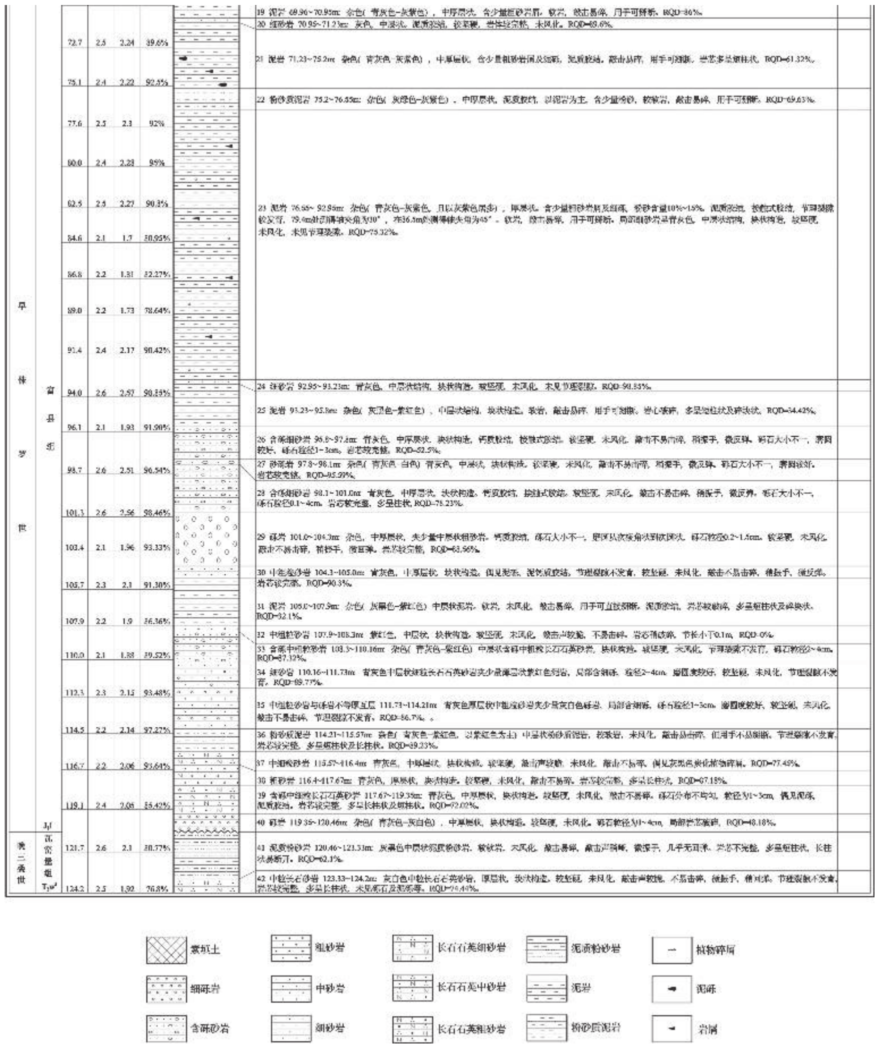

图 6　ZK10 岩芯编录

3.2　多参数测井

测井获取的数据信息包括钻孔深度、视电阻率、声波时差、自然伽玛等地球物理参数以及密度、孔隙度、渗透率等力学参数，根据声波时差和密度计算岩土强度。表 8 为测井数据文件格式说明。以延安工程地质钻孔测井结果统计为例，表 9 为测井结果统计。

图 7 为延安组的钻孔测井曲线特征。图 8 为声波测井资料计算得到的延安组平均强度指数参数值。有等值线图可知，平均强度指数最高值在 ZK04 钻孔处，数值为 26.69 MPa，最低值在 ZK02 钻孔处，数值为 19.89 MPa，整体在 30 ~ 15 MPa，在工程

表 8　测井数据文件格式

数据名称	文件格式
初始数据	txt格式
测井曲线、对比图	mpj格式（MapGIS文件）
等值线图	jpg格式
单孔测井总结	doc格式
技术说明、报告	doc格式、pdf格式

表 9　延安工程地质钻孔测井结果统计表

层位	岩性	视电阻率/(Ω·m)	密度/(g/cm^3)	自然伽玛/*API*	孔隙度/%	渗透率/md^{-1}
		平均	平均	平均	平均	平均
第四系（*Q*）	粉质黏土	60.08	2.13	111.48	10.11	13.36
	粉土	108.12	1.95	109.62	18.58	12.40
	粉砂	21.60	2.10	92.40	10.01	12.02
	细砂	108.04	2.03	81.30	10.96	11.24
	砾石	136.23	2.48	54.30	15.22	12.25
	黄土	140.16	1.98	113.04	16.99	15.16
J_2y^2	砂质泥岩	33.62	2.26	121.58	8.41	10.59
	细粒砂岩	40.74	2.28	106.31	6.13	12.62
	泥岩	21.50	2.37	167.82	7.50	13.52
	中粒砂岩	33.62	2.26	121.58	8.41	10.59
	粉砂岩	31.84	2.40	130.50	7.00	11.24
	细砾岩	37.56	2.21	82.81	9.20	10.25
	粗粒砂岩	42.39	2.07	56.56	10.26	9.56
J_2y^1	砂质泥岩	31.53	2.26	155.29	8.38	10.93
	泥岩	21.22	2.33	160.82	9.60	10.15
	粗粒砂岩	78.45	2.33	58.15	9.82	9.57
	细粒砂岩	60.81	2.30	93.72	9.24	10.18
	中粒砂岩	49.47	2.31	79.19	9.27	10.60
	粉砂岩	46.29	2.46	103.01	13.25	11.34
	细砾岩	226.96	2.41	43.20	13.10	11.24
	中砾岩	53.86	2.44	85.37	7.42	11.17
J_2f	泥岩	15.32	2.43	173.38	8.31	11.42
	砂质泥岩	26.88	2.41	130.50	6.22	10.81
	粗粒砂岩	28.08	2.49	60.62	14.62	9.61
	细粒砂岩	25.36	2.49	118.32	12.62	10.53
	中粒砂岩	35.36	2.37	106.68	11.15	9.84
	粉砂岩	31.12	2.51	143.58	9.05	9.55
T_3w	泥岩	26.29	2.46	184.23	10.82	10.08
	砂质泥岩	41.05	2.45	163.14	9.73	9.78
	中粒砂岩	60.75	2.50	82.99	13.04	9.50
	细粒砂岩	67.70	2.49	110.10	12.83	10.65
	炭质泥岩	25.53	1.93	178.53	9.26	9.53
	泥质粉砂岩	42.91	2.45	164.40	8.53	9.83

地质岩体级别分类属于较软岩石。

3.3　随钻监测

随钻监测获取的数据信息包括钻孔深度、钻杆位移、钻杆转速、油压等钻进参数。表 10 为随钻监测数据名称及文件格式说明。

图 9 是延安工区 ZK07 钻孔的随钻监测结果。可以看出，不同地层的钻进速度有差

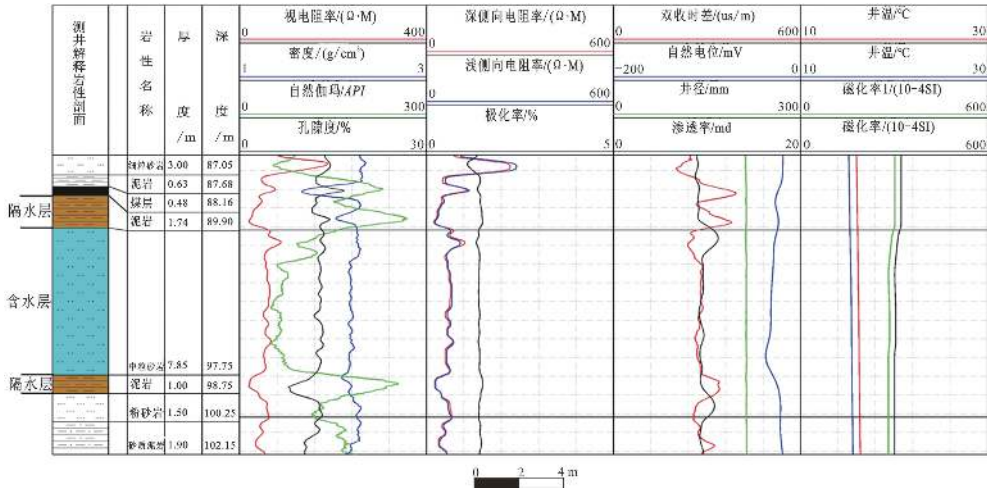

图 7　延安组工程地质钻孔测井曲线特征

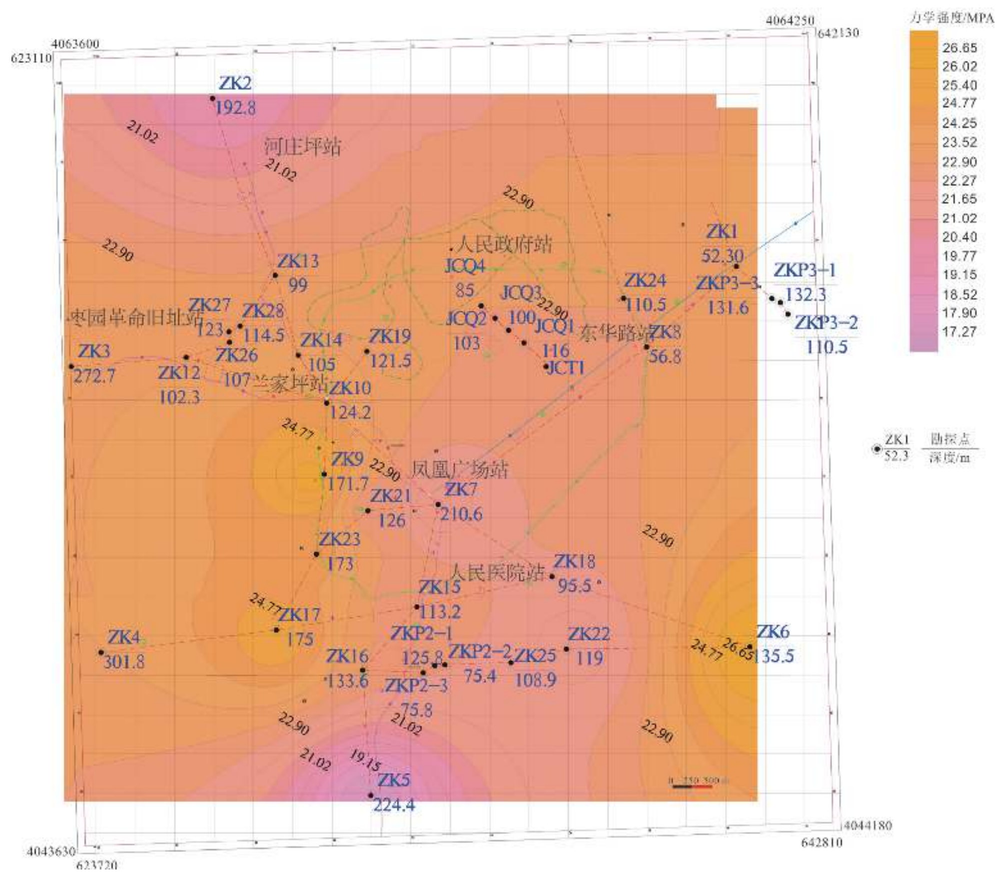

图 8　延安工区地层力学强度等值线图

表 10　随钻监测数据文件格式

数据名称	文件格式
初始数据	txt格式
分析结果	xls格式
随钻参数曲线	srf格式(surfer文件)
技术说明、报告	doc格式

异，富县组泥岩的钻进速度大于富县组细砂岩的钻进速度。不同年代砂泥岩的钻进速度也有差异，富县组砂泥岩的钻进速度大于瓦窑堡组砂泥岩的钻进速度。

从延安工区 ZK19 钻孔的随钻监测结果（图 10）可以看出，不同地层的钻进速度有

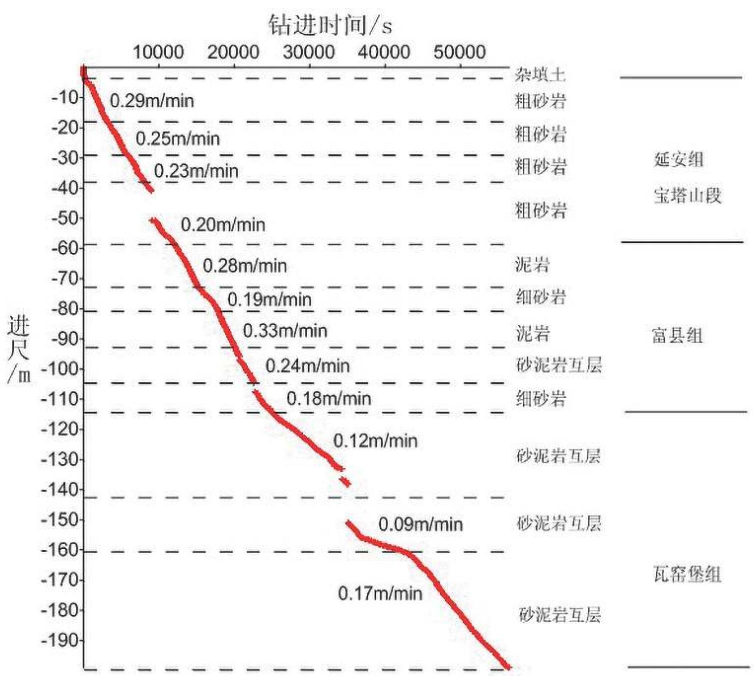

图 9　延安 ZK07 钻孔的随钻监测结果曲线及地层对比

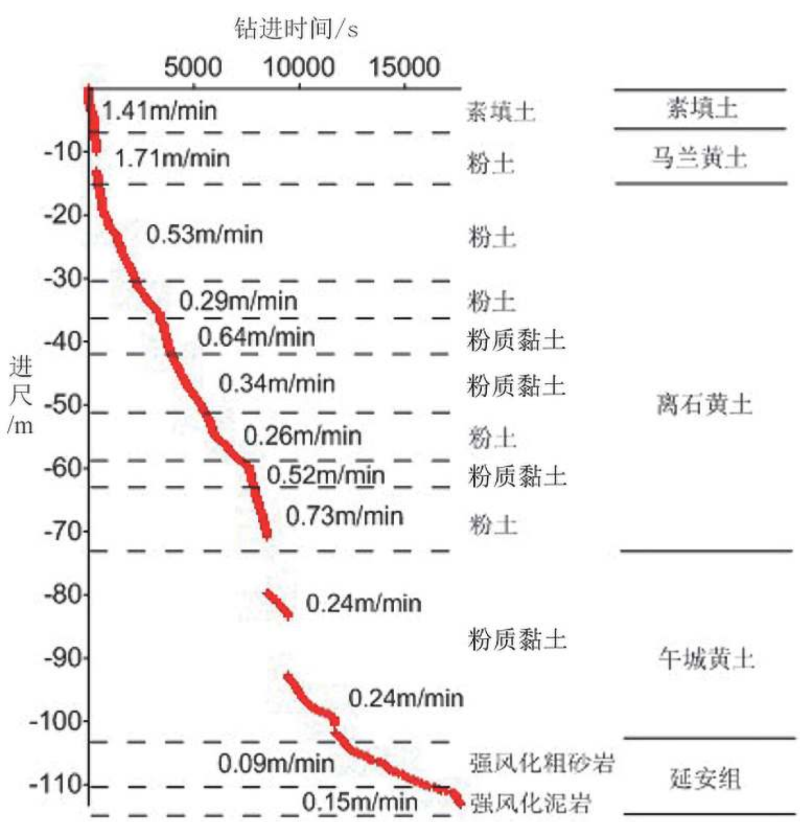

图 10　延安 ZK19 钻孔的随钻监测结果曲线及地层对比

差异，黄土的钻进速度较大，强风化砂泥岩的钻进速度较小。不同年代黄土的钻进速度也有差异，年代越早则黄土的钻进速度越小。

3.4 实验测试

实验测试获取的岩芯数据信息包括取样层位、抗压强度、弹性模量、内聚力等，获取的土样数据信息包括取样层位、含水率、孔隙比、湿陷系数、内聚力等。实验测试数据为 xls 格式。表 11—表 13 是延安钻孔获取的土样和岩芯的物理力学指标试验结果统计。

3.5 地面物探

微动数据处理得到地震波速度剖面，高密度电法数据处理得到电阻率剖面，地质雷达数据处理得到雷达剖面，浅层地震数据处理得到反射地震剖面。物探数据文件夹包含了测线分布图、技术说明、工作报告、综合剖面图。

地面物探获取的数据信息包括深度、视电阻率、地质雷达反射记录、浅层地震反射记录、微动记录，每种方法的初始数据格式不同，都经过专业的软件分析，得到对应的电阻率剖面、地质雷达剖面、地震反射剖面、横波速度剖面。然后，将这些剖面集中并与钻孔资料对比，保存为 jpg 格式。图 11 为西安城市地下空间精细化探测结果，图中包括了高密度电法、浅层地震、微动台阵的探测剖面。

根据多参数地球物理测井资料结合地球物理探测数据，本次试验剖面的地层综合解释结果为：

0.00 ~ 17.40 m 段为细砂、中砂、粉砂、粗砂互层，此段电阻率高，自然电位负异常，声波波速值较低，判断该段推断地层中密，其中 9.35 ~ 17.40 m 为弱含水层段。

17.40 ~ 19.35 m 段为粉质黏土，此段电阻率值呈低值，声波波速值稍高，自然电位无明显异常，推断该段地层密实。

19.35 ~ 73.10 m 段为中砂、细砂互层夹圆砾，此段电阻率值较高，声波波速值稍高，推断该段地层密实。

73.10 ~ 76.50 m 段为粉质黏土夹中砂，此段电阻率值部分呈低值，声波波速较高，自然电位无明显异常，推断该段地层密实。

76.50 ~ 84.85 m 段为中砂，此段电阻率值中低，声波波速值较高，自然电位负异常，为强含水层段，推断该段粒级统一，地层较为坚硬但孔隙度大。

84.85 ~ 87.55 m 段为粉质黏土夹细砂，此段电阻率值低，声波波速值较高，推断该段地层密实。

87.55 ~ 95.00 m 段为细砂、中砂互层，此段电阻率值中值，声波波速值较高，自然电位无明显异常，推断地层较密实。

95.00 ~ 124.00 m 段为中砂，此段电阻率值中低，声波波速值高，自然电位无明显异常，推断地层密实。

4 数据质量控制和评估

工程地质钻探取样和试验测试过程符合相关规范《工程地质钻探规程》（DZ/T 0017−1991），《土工试验方法标准》（GB/T 50123−1999），《岩土工程勘察规范》（GB 50021−2009），《工程地质调查技术要求（1∶50 000）》（DD 2019−06），每天记录和检查相关表格资料。多参数测井符合相关规范（《水文测井工作规范》DZ/T 0181−

表 11 延安黄土及红黏土物理力学指标试验结果统计表

层号	值别	含水率/%	重度/kN·m^{-3}	干重度/kN·m^{-3}	孔隙比	饱和度/%	液限/%	塑限/%	塑性指数/%	液性指数/%	压缩系数/MPa^{-1}	湿陷系数	内聚力/kPa	内摩擦角/°
晚更新世黄土	统计频数	30	29	29	29	29	30	30	30	30	29	15	8	8
	最大值	20.2	19	16.8	1.31	76.0	28.2	17.5	11.0	0.72	0.2	0.099	62.1	32.2
	最小值	3.0	13.3	12.4	0.61	15.0	24.6	16.7	9.4	<0	0.1	0.030	22.1	15.3
	平均值	12.72	15.9	14.1	0.94	38.86	27.13	17.15	9.89		0.19	0.075	33.54	24.1
	标准差	4.77	1.6	1.1	0.16	17.0	0.47	0.12	0.3		0.08		13.33	5.31
	变异系数	0.38	0.10	0.08	0.17	0.44	0.02	0.01	0.04		0.44		0.40	0.22
中更新世黄土	统计频数	127	127	127	127	127	126	128	128	129	126	12	60	60
	最大值	22.6	21.0	18.1	0.987	98.0	29.9	17.9	12.0	0.92	0.46	0.078	75.8	45.0
	最小值	4.9	16.8	13.8	0.482	38.0	24.3	16.6	7.7	0.0	0.07	0.004	10.8	13.6
	平均值	18.39	19.0	16.0	0.7	71.94	29.16	17.46	11.7	0.17	0.13	0.013	45.41	29.81
	标准差	3.73	0.9	0.8	0.09	12.9	1.91	0.74	0.24	0.20	0.06		19.33	7.06
	变异系数	0.20	0.05	0.05	0.12	0.18	0.07	0.04	0.11	1.19	0.43		0.43	0.24
红黏土	统计频数	4	4	3	4	3	4	4	4	4	4	4	4	4
	最大值	17.60	20.9	18.8	0.618	91.6	30.7	21.2	11.7	0.71	0.12	0.005	450.8	54.5
	最小值	7.07	17.5	17.8	0.443	66.9	25.9	16.8	9.1	0.57	0.02	0.002	41.65	24.0
	平均值	11.99	19.2	18.2	0.517	75.56	29.03	18.9	10.2	0.67	0.08	0.003	201.8	32.4

表 12　延安砂岩物理力学指标试验结果统计表

统计指标		统计数	最大值	最小值	平均值	标准差	变异系数
饱和容重/g·cm^{-3}		36	2.72	2.66	2.68	0.02	0.01
比重		36	2.54	2.23	2.31	0.09	0.03
普通吸水率		36	6.92	6.26	6.53	0.22	0.03
软化系数		36	0.72	0.57	0.67	0.05	0.11
抗拉强度/MPa		36	2.4	1.5	1.97	0.28	0.14
单轴抗压强度/MPa	干燥	36	75.1	43.0	61.2	10.9	0.20
	饱水	36	51.3	28.2	41.2	9.07	0.22
弹性模量/MPa		36	4583	3865	4203	233.4	0.10
泊松比		36	0.26	0.17	0.22	0.03	0.12
内聚力/MPa		36	4.6	3.9	4.23	0.24	0.10
内摩擦角/°		36	43.5	40.0	41.6	1.00	0.02

表 13　延安泥岩物理力学指标试验结果统计表

统计指标		统计数	最大值	最小值	平均值	标准差	变异系数
单轴抗压强度/MPa	干燥	33	1.336	0.747	0.944	0.15	0.16
	饱水	33	0.774	0.311	0.502	0.16	0.31
弹性模量/MPa		33	9.8	6.86	7.26	2.08	0.25
泊松比		33	0.30	0.25	0.26	0.04	0.13
内聚力/kPa		33	71.1	16.7	53.85	3.8	0.21
内摩擦角/°		33	35	21	26	1.0	0.16

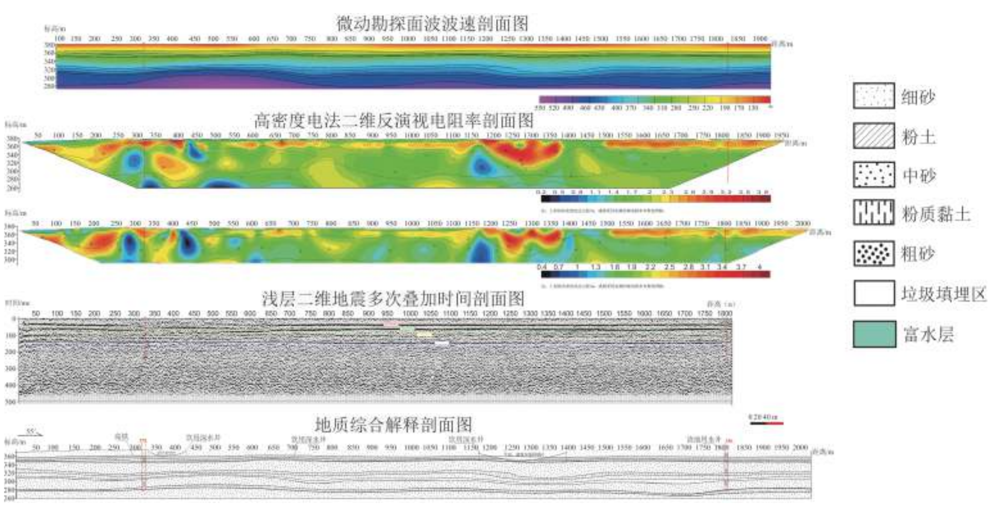

图 11　西安地下空间探测综合剖面及解释结果

1997）。城市地下空间探测的地球物理方法选取合理，各方法实施过程符合相关规范《城市工程地球物理探测规范》（CJJ 7−2007），数据处理由专业人员实施。随钻监测技术目前还不完善，没有相关规范，其数据采集和处理过程根据已有研究基础实施。

5　数据价值

由于城市强干扰的物理场环境、复杂的地质环境条件和既有建筑物影响，城市地下

空间探测的理论和技术方法尚不成熟，传统的方法和目前开展的地质调查工作不能完全满足城市地下空间资源评价和开发利用规划的需求。为此，本次工作将岩体勘探随钻监测技术引入了第四纪松散堆积层，并选择自然伽玛、自然电位、密度、声波时差、双侧向电阻率、极化率、磁化率、伽玛能谱、井温、井径、井斜等 13 个参数进行了井中物探，形成了钻探与随钻监测结合、地面物探与井中物探结合、原位试验与室内测试结合，克服强干扰环境的地下空间探测组合技术方法，获取了宝贵的数据。本数据集工作区域涵盖了陕西省秦巴山地、关中盆地和黄土高原，数据具有较强的代表性。所获数据对于岩土体质量评价、城市三维地质全要素建模、地下空间资源评价、岩土体质量与物性参数耦合关系研究、城市地质与岩土工程实践和科学研究均具有十分重要的价值。

6 结论

干扰环境下城市地下空间组合探测与全要素数据集采自秦岭山地、关中盆地和黄土高原，包括工程地质钻探、实验测试、多参数测井、随钻监测和地面物探数据 5 个文件夹，其中工程地质钻孔 144 个，实验测试样品 672 个，物探测井 13 类参数 111 个孔，随钻监测 36 个孔，地面物探 4 类方法 5 条剖面，共计 968 组数据，3 664 个文件，格式包含 jpg，xls，doc，mpj，dwg。

钻孔数据包括施工日期、钻孔深度、地层岩性描述、分层序号、分层厚度、取样深度；测井数据包括自然伽玛、自然电位、密度、声波时差、双侧向电阻率、极化率、磁化率、伽玛能谱、井温、井径、井斜；随钻监测数据包括测量时间、钻进回次、加杆长度、钻孔深度、油缸位移、钻杆转速、油压、扭压；实验测试数据包括：土样测试数据为含水率、天然密度、粘聚力、内摩擦角、自重湿陷系数、比表面积，岩芯测试数据为声波速度、单轴抗压强度；地面物探数据包括：探测方法、排列装置、测量点数、测线长度、采样间隔。该数据集可用于岩土体质量评价、城市三维地质全要素建模、地下空间资源评价、岩土体质量与物性参数耦合关系研究、城市地质与岩土工程实践和科学研究。

在地质调查过程中，逐步形成一套强干扰环境下城市地质与地下空间多参数探测技术组合，积累了一批宝贵的数据，鉴于我们精力和能力所限，以及公益性地质工作性质要求，本次毫不保留地向社会提供数据和数据说明，实现数据共享，希冀吸纳海内外专家、学者、研究生共同研究。

致谢：感谢香港大学岳中琦教授、陈帝酒高级技师，西北大学谷天峰副教授，中国地质大学 (北京) 张中俭副教授在随钻监测技术方法与监测仪器方面的鼎力支持，感谢陕西工程勘察研究院有限公司刘贤斌院长、周晓燕副总工程师和中国煤炭地质总局航测遥感局王辉院长、郭瑞华项目负责人组织实施了主要的工程地质钻探，感谢陕西地矿物化探队有限公司刘建利、余常忠副总经理组织实施了物探工作。感谢审稿人和编辑部在稿件修改过程中提出了的宝贵意见。

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doi: 10.12029/gc2019Z204

Article Citation: Zhang Maosheng, Wang Yimin, Zhang Ge, Dong Ying, Sun Pingping, Jia Jun. 2019. All-Element Dataset of Combined Exploration of Urban Underground Spaces with Strong Interference[J]. Geology in China, 46(S2):42−66.

Dataset Citation: Zhang Maosheng; Wang Yimin; Zhang Ge; Dong Ying; Sun Pingping; Jia Jun. All-Element Dataset of Combined Exploration of Urban Underground Spaces with Strong Interference(V1). Xi'an Center, China Geological Survey; Shaanxi Engineering Technical Research Center of Water Resources and Environment[producer], 2013. National Geological Archives of China [distributor], 2019-12-30. 10.23650/data.D.2019.P14; http://dcc.cgs.gov.cn/en/data/doi/10.23650/data.D.2019.P14

Received: 23-10-2019
Accepted: 08-11-2019

Fund Project:
China Geological Survey projects titled "Risk Assessment of Geologic Disasters in Important Towns in Shaanxi" (DD20160261) and "Comprehensive Geological Survey in Guanzhong – Tianshui Economic Region" (DD20189220) and "Multi-element Urban Geological Survey in Xi'an and Comprehensive Geological Survey in Yan'an, a Former Base of the Communist Party of China" (DD20189270).

All-Element Dataset of Combined Exploration of Urban Underground Spaces with Strong Interference

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Abstract: The utilization of underground space has become a major means of solving the problems plaguing cities, and the precise exploration of underground space is fundamental to its development and utilization. However, the theories, method combination, elements to be acquired and data application regarding the exploration of urban underground space with strong interference are yet to be determined in a united manner. The all-element dataset of combined exploration of urban underground space with strong interference (also referred to as the Dataset) relies on these four projects initiated by the China Geological Survey: *Risk Assessment of Geologic Disasters in Important Towns in Shaanxi Province* (2013—2016), *Comprehensive Geological Survey in Guanzhong – Tianshui Economic Region* (2016—2018), *Multi-element Urban Geological Survey in Xi'an* (2018—2021) and *Comprehensive Geological Survey in Yan'an, a Former Base of the Communist Party of China* (2018—2021). The aim of these projects were to meet the demand for quality assessment of rock and soil masses and also the assessment, development and utilization of urban underground space. During the development of the Dataset, monitoring-while-drilling (MWD) technology was introduced based on regular geophysical prospecting, drilling and testing. Furthermore, a total of 13 parameters was logged, a combined method of underground space exploration was established and the all-element data required for quality assessment of rock and soil masses and urban underground space were obtained. The data in the Dataset were obtained from the urban area of Shanyang County, in the Qinba Mountains of Shaanxi Province, the urban area of Xi'an City in the Guangzhong Basin and the urban area of Yan'an City in the Loess Plateau. It

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consists of five types of data, i.e., engineering geological drilling, testing, multi-parameter logging, MWD and ground geophysical prospecting. In detail, the data were acquired from 144 engineering geological boreholes, 672 testing samples, 111 boreholes for the logging of 13 parameters by geophysical prospecting, 36 MWD boreholes and 5 profiles of ground geophysical prospecting obtained via 4 methods. In total, the Dataset consists of 968 sets of data and 3 664 files in the formats of .jpg, .xls, .doc, .mpj and .dwg. It can be applied to the quality assessment of rock and soil masses, the establishment of 3D urban geological all-element models, the assessment of underground space resources, the research on the coupling relationship between the quality and physical properties of rock and soil masses and the scientific research of urban geology.

Key words: drilling; monitoring while drilling (MWD); ground geophysical prospecting; multi-parameter logging; underground space; urban geological survey engineering; Xi'an

Data service system URL: http://dcc.cgs.gov.cn

1 Introduction

With increasingly quick urbanism in China, more and more cities are confronted with problems such as a serious shortage of space and a worsening environment (Qian QH, 1998). This imposes a greater importance on urban geological work (Zhang MS et al., 2014). The development and utilization of underground space are necessary to guarantee the sustainable development of modern cities since additional space can be gained for urban infrastructure, living and services (Bobylev N, 2009; Broere, 2016; Zhang MS et al., 2018; Wang HQ et al., 2019). Therefore, the development and utilization of underground space have become a major means of solving the problems currently plaguing cities.

Different geological environmental conditions must be taken into consideration for the development and utilization of underground space in different cities. For example, in the cities located in mountainous or hilly areas, although the topography and landform result in severe shortage of ground space, the geological environmental conditions facilitate the development and utilization of underground space (Zhang MS et al., 2019; Yang WC et al., 2019). In famous historic and cultural cities, the protection of underground historic relics must be considered in the development of the underground space (Qiao YK et al., 2017); in cities suffering from geological environmental problems such as ground subsidence, land cracks, active structures, loess collapse, sand liquefaction and geological disasters, the environmental geological conditions that limit the development and utilization of underground space must be ascertained (Zhang MS et al., 2013; Tian ZY et al., 2019; Zhang SS et al., 2019; Zhou YX et al., 2019; Qi BS et al., 2019).

Precise exploration of underground space and geological environmental conditions is fundamental to the assessment, development and utilization of the underground space (Wang YH et al., 2019) and it will provide data for the establishment of 3D urban geological models (He J et al., 2019). Unfortunately, there is still no concrete theory on underground exploration as it is complicated by intricate geological environmental conditions and existing city buildings (Chen W, 2006; Zhao P et al., 2017). Meanwhile, the technology, method combination, elements to be acquired and data application regarding the exploration of urban underground space with strong interference are not normative yet and fall behind practical demand. Therefore, all these constitute the critical elements of the precise exploration of urban underground space. Moreover, current geological surveys and data obtained fail to fully satisfy the demand for the assessment and planning of the development and utilization of urban underground space.

The project titled *Risk Assessment of Geological Disasters in Important Towns in Shaanxi (Shanyang County)* initiated by the China Geological Survey was carried out in 2013—2016. In order to scientifically assess the quality of rock and soil masses, explore the weak structural planes, and thus provide a judgment basis for a risk assessment of geological disasters, the MWD technology researched and developed by Professor Yue Zhongqi from the University of Hong Kong (Yue ZQ et al., 2004; Yue ZQ, 2014) was introduced into the project by collaborating with the professor himself. As a result, the first batch of MWD data was obtained.

For the purpose of serving the quality assessment of rocks and soil masses, the assessment of underground space resource, and 3D geological modeling that were oriented towards shield tunneling method during the implementation of the project titled *Comprehensive Geological Survey in Guanzhong – Tianshui Economic Region* (2016—2018) initiated by China Geological Survey in 2017, a combined exploration method of underground space was conducted in Xixian New Area, Xi' an, and MWD was tried in the Quaternary loose deposits in Baqiao District, Xi' an. Furthermore, the equipment for MWD was improved by cooperating with Associate Professor Gu Tianfeng from Northwest University, and 13 parameters were selected for logging of geophysical prospecting. As a result, the data of drilling and MWD of two test boreholes and the data from logging the 13 parameters were obtained successfully; and a combined exploration method of underground space was established.

Two second-level projects named *Multi-Element Urban Geological Survey in Xi' an* (2018—2021) and *Comprehensive Geological Survey in Yan' an, a Former Base of the Communist Party of China* (2018—2021) were launched in 2018. Comprehensive geophysical prospecting, MWD and the logging of 13 parameters were conducted based on regular geophysical prospecting, drilling and testing in order to meet the demand of the project in terms of the quality assessment of rock and soil masses and the assessment, development and utilization of urban underground space. As a result, the all-element data required for the quality assessment of both rock and soil masses as well as urban underground space were obtained in comparison with the multi-element urban geological survey currently implemented by the China Geological Survey.

The data in the Dataset were collected from the urban area of Shanyang County, the Qinba Mountains in Shaanxi Province, the urban area of Xi'an City in the Guanzhong Basin and the urban area of Yan'an City in the Loess Plateau. It consists of five types of data, i.e., engineering geological drilling, testing, multi-parameter logging, MWD and ground geophysical prospecting. In detail, the data were acquired from 144 engineering geological boreholes, 672 testing samples, 111 boreholes for logging of 13 parameters by geophysical prospecting, 36 MWD boreholes and 5 profiles of ground geophysical prospecting obtained via 4 methods. In total, the Dataset consists of 968 sets of data and 3 664 files in the formats of .jpg, .xls, .doc, .mpj and .dwg. The metadata table of the Database (Dataset) is shown in Table 1.

2 Methods for Data Acquisition and Processing

The Dataset covers the urban areas of Shanyang County in the Qinba Mountains, Xi'an in the Guanzhong Basin and Yan' an City in the Loess Plateau, Shaanxi Province. The geographical locations and relief of these working areas are shown in Fig. 1.

2.1 Engineering Geological Drilling

Geotechnical drilling is aimed at revealing the structure and engineering geological properties of strata and building 3D geological structural models. There were 144 engineering geological boreholes in total to be drilled for the Dataset, including 104 in the Xi'an working area (Fig. 2), 32 in the Yan'an working area (Fig. 3) and 8 in the Shanyang working area (Fig. 4). The basic information of the boreholes is shown in Tables 2–4.

2.2 Multi-parameter Logging

The logging data are kept in two folders, labelled "Xi'an" and "Yan'an". The data in each folder include the information of single boreholes, comparison diagrams, isoline maps and summary reports. All-element logging was conducted for 98 boreholes drilled in the Xi' an working area and 13 boreholes drilled in the Yan'an working area. Multiple logging methods (parameters) were adopted such as natural gamma ray, spontaneous potential, density, acoustic interval transit time, dual laterolog resistivity, polarizability, magnetic susceptibility, gamma-ray spectrometry and well temperature, diameter (with caliper log) and deviation. A digital logging instrument, KH-2, was used with the measuring speed of 6–10 m/min. During the data acquisition, the appropriate technical specifications were followed for each logging method. The characteristics of the logging parameters of strata can be obtained by using statistics Mechanical parameters can be calculated using the acoustic speed and density. Furthermore, the isoline maps of the logging parameters of the working areas can be prepared based on the data of all single boreholes.

2.3 Monitoring-While-Drilling (MWD)

MWD data are kept in three folders, labelled "Xi' an", "Yan' an" and "Shanyang". Additionally, there are instructions for the use of the MWD system and files on the analytical process used for the MWD data. The data in each folder contain initial data, data table of MWD records, files of data analysis process and maps as results. MWD data were processed in Excel, the analytical process of the MWD data was saved into Word files and then after the data was processed, they were used to prepare maps with the software, Surfer. The MWD data respectively cover 22, 6 and 8 boreholes drilled in Xi'an, Yan'an and Shanyang. The MWD system, developed independently by the University of Hong Kong including displacement sensors, rotational speed sensors, oil pressure sensors, torsional pressure sensors and data

Table 1 Metadata Table of Database (Dataset)

Items	Description
Database (dataset) name	All-Element Dataset of Combined Exploration of Urban Underground Spaces with Strong Interference
Database (dataset) authors	Zhang Maosheng, Xi'an Center, China Geological Survey; Shaanxi Engineering Technical Research Center of Water Resources and Environment Wang Yimin, Xi'an Center, China Geological Survey; Shaanxi Engineering Technical Research Center of Water Resources and Environment Zhang Ge, Xi'an Center, China Geological Survey; Shaanxi Engineering Technical Research Center of Water Resources and Environment Dong Ying, Xi'an Center, China Geological Survey; Shaanxi Engineering Technical Research Center of Water Resources and Environment Sun Pingping, Xi'an Center, China Geological Survey; Shaanxi Engineering Technical Research Center of Water Resources and Environment Jia Jun, Xi'an Center, China Geological Survey; Shaanxi Engineering Technical Research Center of Water Resources and Environment
Data acquisition time	2013—2018
Geographical area	Xi'an City, located at E 107°24′–109°30′ and N 33°24′–34°24′ Yan'an, located at E 109°22′–109°37′ and N 36°27′–36°40′ Shanyang County, located at E 109°50′10″–109°56′57″ and N 33°30′27″–33°33′05″
Data format	.jpg, .xls, .doc, .mpj, .dwg
Data size	1.19 GB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	China Geological Survey projects titled "Risk Assessment of Geological Disasters in Important Towns in Shaanxi" (DD20160261) and "Comprehensive Geological Survey in Guanzhong – Tianshui Economic Region" (DD20189220) and "Multi-element Urban Geological Survey in Xi'an and Comprehensive Geological Survey in Yan'an, a Former Base of the Communist Party of China" (DD20189270)
Language	Chinese
Database (dataset) composition	Data of drilling: the No., geographical location and coordinates of borehole, elevation of borehole head, drilling rig type, drilling method, drilling date, borehole depth, stratigraphic lithologic description, sub-layer No., sub-layer depth and sampling depth Data of logging: measuring date, measuring depth, natural gamma ray, spontaneous potential, density, interval transit time, dual laterolog resistivity, polarizability, magnetic susceptibility, gamma-ray spectrometry and the temperature, diameter and deviation of well Data of MWD: measuring date, drilling roundtrip, length of added drill rod, borehole depth, cylinder displacement, drill rod rpm, oil pressure and torsion pressure Data of testing: testing data of soil samples consisting of sample No., sampling depth, moisture content, natural density, cohesive force, inner friction angle, coefficient of self-weight collapsibility and specific surface area; testing data of core samples including sample No., sampling depth, acoustic velocity and uniaxial compressive strength Data of ground geophysical prospecting: measuring date, prospecting method, electrode arrangement device, number of measuring points, length of measuring line and sampling interval

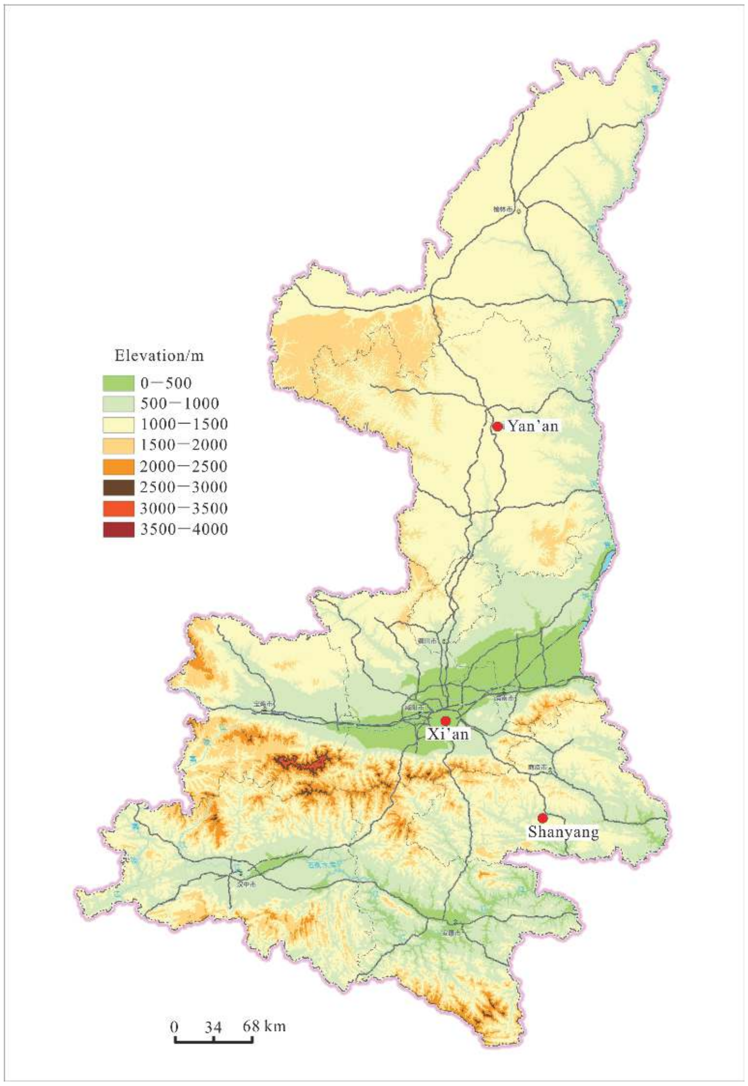


Fig. 1 Xi'an – Yan'an – Shanyang relief map

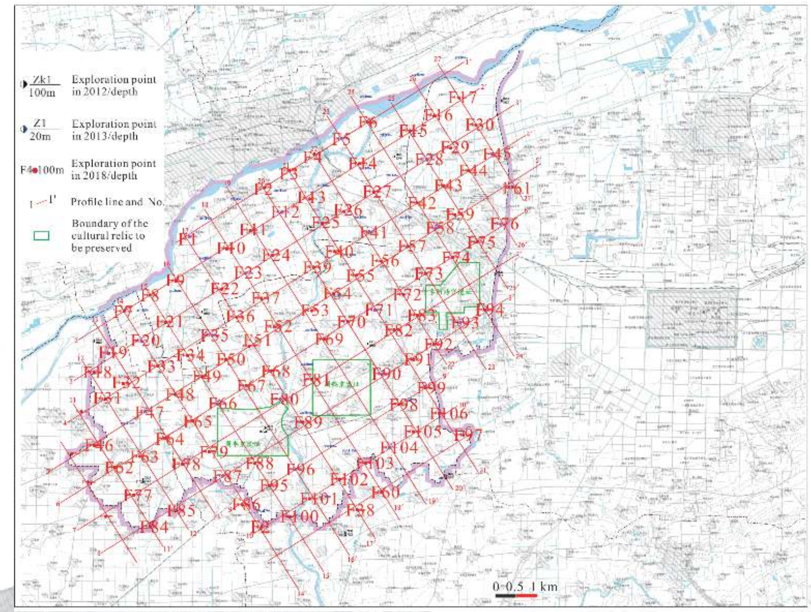


Fig. 2 Distribution map of the engineering geological boreholes in Xi'an

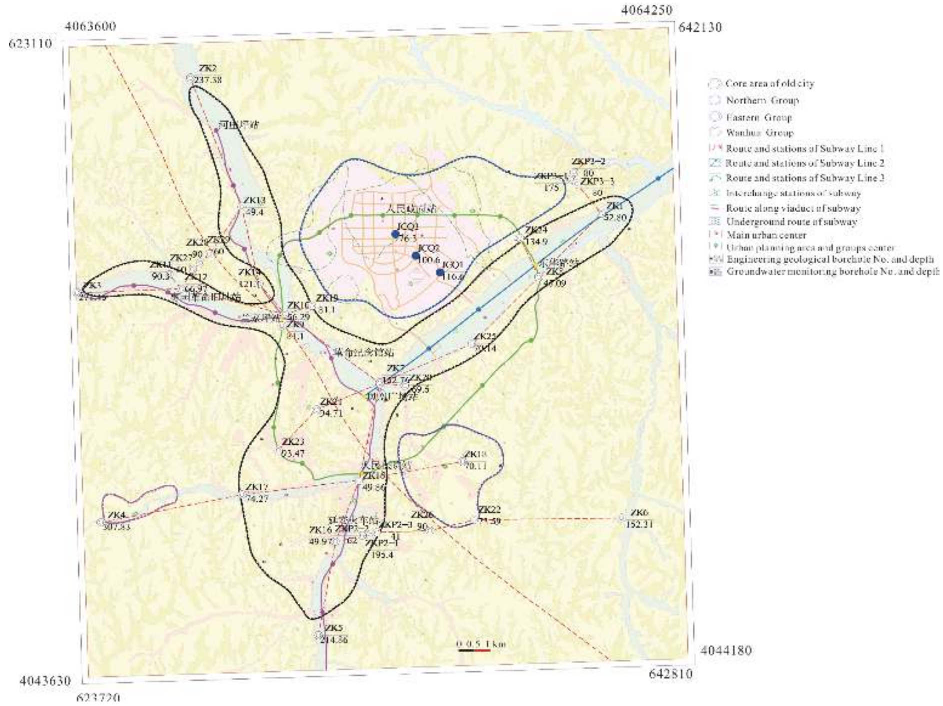


Fig. 3 Distribution map of engineering geological boreholes in Yan'an

Fig. 4 Distribution map of engineering geological boreholes in Shanyang County

acquisition devices, was adopted; with a sampling interval of 1–2 sec. As for the processing of the MWD data, the effective data was extracted from the initial data to represent the drilling processes, and then the footage, drilling period and drilling speed were calculated. The conditions used to determine effective MWD data during the extraction from the initial data are shown in Table 5.

Drilling time—footage curve, drilling speed—footage curve, rotational speed—footage curve, oil pressure—footage curve, torsional pressure—footage curve can be prepared based on the effective data extracted.

2.4 Testing

Testing data were saved into a total of three Excel files. The testing data of the soil samples include sample No., sampling depth, moisture content, natural density, cohesive force, inner friction angle, the coefficient of self-weight collapsibility and specific surface area. The testing data of the core samples include sample No., sampling depth, acoustic velocity and uniaxial compressive strength.

2.5 Ground Geophysical Prospecting

Refined geophysical prospecting tests of underground space were conducted in Xi' an (Table 6). There are many interfering factors in cities, including strong electromagnetic and vibrational interference. Since both the high-density resistivity method and the microtremor array feature deep exploration, whereas ground penetrating radar features high resolution, these methods were jointly adopted in the same working area and the results of each method were analyzed. The schematic diagram of urban underground space exploration in Xi'an is shown in Fig. 5. For the microtremor array method, the smart microtremor explorer, WD-1, was used and triangular arrays were embedded with a minimum interval of 6–10 m, and the sampling interval was 10 ms. As for the high-density resistivity method, the multi-function DC electrical prospecting apparatus, EDJD-1, was utilized. It was equipped with the Wenner array and the interval between the electrodes was 5 m. And for the ground-penetrating radar method, the geological radar SIR-4000, attached with antennae of 100 and 200 MHz, was used and the sampling interval was set at 1 m. As for the shallow seismic prospecting, the multi-channel distributed engineering seismograph, SE2404NT, and geophones of 60 Hz were used. Furthermore, multiple coverage and seismic reflection were implemented and seismic energy was unilaterally excited with a sledgehammer. The parameters and their values used in the shallow seismic prospecting are as follows: trace space–4 m, coverage times–8 times, sampling interval–0.5 ms and record length–512 ms.

3 Description of Data Samples

3.1 Engineering Geological Drilling

The data obtained from geotechnical drilling include information from the borehole depth and stratum core samples. Synthetic histograms of strata revealed by boreholes were prepared based on manually recording the data from geotechnical drilling and then digitalized. The borehole data and their file formats are shown in Table 7.

The Comprehensive Stratigraphic Column of the ZK10 in Yan'an is described in Fig. 6. The Column contains sandstone and mudstone developed in the Yan' an Formation, Fuxian Formation and Wayaobao Formation, reflecting the structure of sedimentary strata in Yan'an work area.

3.2 Multi-parameter Logging

The data obtained from logging include geophysical parameters such as borehole depth, apparent resistivity, acoustic interval transit time and natural gamma-ray, and also mechanical

Table 2 Basic Information of Engineering Geological Boreholes in Xi'an

Borehole No.	Borehole depth/m	Lithology recorded	Logging	MWD	Testing
Bailuyuan	200.00	Loess, silty clay, sandy gravel layer		Yes	
Airport	200.00	Loess, silty clay, fine sand, sandy gravel layer		Yes	
F1	150.00	Fine sand, medium sand, silty clay, sandy gravel layer	Yes		
F2	100.00	Loess-like soil, silty clay, medium sand, coarse sand			
F3	100.00	Loess-like soil, silty clay, fine sand, medium sand			
F4	100.00	Loess-like soil, silty clay, fine sand, medium sand, sandy gravel layer	Yes		
F5	100.00	Loess-like soil, medium sand, sandy gravel layer	Yes		
F6	100.00	Loess-like soil, silty clay, fine sand, coarse sand	Yes		
F7	100.20	Loess-like soil, silty clay, coarse sand, gravelly sand			
F8	100.00	Loess-like soil, silty clay, fine sand, medium sand			
F9	100.00	Silty clay, fine sand, medium sand, and sandy gravel layer	Yes		
F10	100.00	Loess-like soil, silty clay, fine sand, medium sand, gravelly sand	Yes		Soil sample
F11	100.00	Loess-like soil, silty clay, fine sand, medium sand, gravelly sand, sandy gravel layer	Yes		
F12	150.00	Loess-like soil, silty clay, fine sand, medium sand, coarse sand, sandy gravel layer	Yes		Soil sample
F13	100.00	Silty clay, fine sand, medium sand, coarse sand, gravelly sand, sandy gravel layer	Yes		
F14	100.00	Silty clay, fine sand, medium sand, coarse sand, gravelly sand	Yes	Yes	Soil sample
F15	100.00	Silty clay, fine sand, medium sand, coarse sand	Yes		
F16	100.00	Silty clay, fine sand, medium sand, coarse sand	Yes	Yes	Soil sample
F17	100.00	Silty clay, fine sand, medium sand, coarse sand	Yes		Soil sample
F18	100.10	Silty clay, fine sand, medium sand, coarse sand, gravelly sand, sandy gravel layer	Yes		
F19	100.00	Medium sand, gravelly sand, sandy gravel layer	Yes	Yes	Soil sample
F20	150.00	Silty clay, fine sand, medium sand, gravelly sand, sandy gravel layer	Yes	Yes	Soil sample
F21	100.00	Silty clay, fine sand, medium sand, coarse sand, gravelly sand, sandy gravel layer	Yes		Soil sample
F22	100.00	Loess-like soil, silty clay, fine sand, medium sand, coarse sand, gravelly sand	Yes		Soil sample
F23	150.00	Silty clay, fine sand, medium sand, coarse sand, gravelly sand, sandy gravel layer	Yes		Soil sample
F24	100.00	Loess-like soil, silty clay, fine sand, medium sand	Yes		
F25	100.00	Silty clay, fine sand, medium sand, coarse sand, gravelly sand	Yes		Soil sample
F26	100.00	Silty clay, fine sand, medium sand, sandy gravel layer	Yes		Soil sample
F27	100.00	Silty clay, medium sand, coarse sand	Yes	Yes	Soil sample
F28	150.00	Silty clay, fine sand, coarse sand	Yes		Soil sample
F29	100.00	Silty clay, fine sand, coarse sand	Yes		Soil sample
F30	100.00	Silty clay, fine sand, coarse sand	Yes		
F31	100.00	Silty clay, fine sand, medium sand, coarse sand, gravelly sand	Yes		Soil sample

Continued table 2

Borehole No.	Borehole depth/m	Lithology recorded	Logging	MWD	Testing
F32	100.00	Silty clay, fine sand, medium sand, coarse sand, gravelly sand, sandy gravel layer	Yes		Soil sample
F33	100.00	Silty clay, fine sand, medium sand, gravelly sand, sandy gravel layer			Soil sample
F34	100.00	Silty clay, fine sand, medium sand, gravelly sand	Yes		Soil sample
F35	150.00	Loess-like soil, silty clay, fine sand, medium sand, coarse sand, gravelly sand	Yes		Soil sample
F36	100.00	Silty clay, fine sand, medium sand, coarse sand, sandy gravel layer	Yes		Soil sample
F37	100.00	Silty clay, fine sand, medium sand, coarse sand	Yes		Soil sample
F38	100.00	Loess-like soil, silty clay, fine sand, medium sand, coarse sand	Yes		
F39	100.00	Silty clay, fine sand, medium sand, coarse sand, sandy gravel layer	Yes		Soil sample
F40	100.20	Silty clay, fine sand, medium sand, gravelly sand	Yes		
F41	150.00	Silty clay, fine sand, medium sand, coarse sand	Yes	Yes	Soil sample
F42	100.00	Fine sand, medium sand, coarse sand	Yes		Soil sample
F43	100.00	Silty clay, fine sand, medium sand, coarse sand	Yes	Yes	
F44	100.00	Silty clay, fine sand, medium sand, coarse sand, gravelly sand, sandy gravel layer	Yes		Soil sample
F45	150.00	Silty clay, fine sand, medium sand, coarse sand	Yes	Yes	Soil sample
F46	100.00	Silty clay, fine sand, medium sand, coarse sand, gravelly sand, sandy gravel layer	Yes		Soil sample
F47	150.00	Loess-like soil, silty clay, fine sand, medium sand, gravelly sand, sandy gravel layer	Yes	Yes	Soil sample
F48	100.00	Loess-like soil, silty clay, fine sand, medium sand, coarse sand, gravelly sand, sandy gravel layer	Yes		
F49	100.00	Silty clay, fine sand, medium sand, coarse sand, gravelly sand	Yes		Soil sample
F50	100.00	Silty clay, fine sand, medium sand, coarse sand, gravelly sand, sandy gravel layer	Yes		Soil sample
F51	100.00	Silty clay, fine sand, medium sand, sandy gravel layer	Yes		Soil sample
F52	100.00	Fine sand, medium sand, gravelly sand	Yes		Soil sample
F53	100.00	Silty clay, fine sand, medium sand, gravelly sand	Yes		Soil sample
F54	100.00	Silty clay, fine sand, medium sand, coarse sand, gravelly sand	Yes		Soil sample
F55	100.00	Silty clay, fine sand, medium sand, coarse sand, gravelly sand	Yes		Soil sample
F56	100.00	Silty clay, fine sand, medium sand, gravelly sand	Yes		
F57	100.00	Silty clay, fine sand, medium sand, coarse sand	Yes	Yes	Soil sample
F58	150.00	Silty clay, fine sand, medium sand, coarse sand, sandy gravel layer	Yes	Yes	Soil sample
F59	100.00	Silty clay, fine sand, medium sand, gravelly sand	Yes		Soil sample
F60	100.50	Loess-like soil, silty clay, fine sand, medium sand	Yes		
F61	100.00	Silty clay, fine sand, medium sand, gravelly sand	Yes		Soil sample
F62	100.40	Loess-like soil, silty clay, medium sand	Yes		
F63	100.00	Silty clay, medium sand, gravelly sand	Yes		
F64	100.00	Silty clay, fine sand, medium sand, sandy gravel layer	Yes	Yes	Soil sample

Continued table 2

Borehole No.	Borehole depth/m	Lithology recorded	Logging	MWD	Testing
F66	150.00	Loess-like soil, silty clay, fine sand, medium sand, sandy gravel layer	Yes	Yes	
F67	100.10	Silty clay, fine sand, medium sand, coarse sand, gravelly sand	Yes		
F68	100.00	Silty clay, fine sand, medium sand, sandy gravel layer	Yes		Soil sample
F69	100.00	Silty clay, fine sand, medium sand	Yes		Soil sample
F70	100.00	Silty clay, fine sand, medium sand, coarse sand	Yes	Yes	Soil sample
F71	150.00	Silty clay, fine sand, coarse sand, gravelly sand	Yes	Yes	Soil sample
F72	100.00	Silty clay, fine sand, medium sand	Yes	Yes	Soil sample
F73	100.00	Silty clay, fine sand, medium sand	Yes		Soil sample
F74	100.00	Silty clay, fine sand, medium sand, coarse sand	Yes		Soil sample
F75	100.00	Silty clay, fine sand, medium sand	Yes		Soil sample
F76	150.00	Silty clay, fine sand, medium sand, coarse sand, gravelly sand	Yes		Soil sample
F77	100.20	Silty clay, fine sand, medium sand, coarse sand	Yes		
F78	100.10	Loess-like soil, silty clay, medium sand, coarse sand, gravelly sand			
F79	100.10	Silty clay, fine sand, medium sand, coarse sand	Yes		
F80	150.10	Silty clay, fine sand, medium sand, gravelly sand	Yes		
F81	100.50	Silty clay, fine sand, medium sand, coarse sand, gravelly sand	Yes		
F82	100.30	Silty clay, fine sand, medium sand	Yes		
F83	100.00	Silty clay, fine sand, medium sand, gravelly sand, sandy gravel layer	Yes		Soil sample
F84	100.50	Loess-like soil, silty clay, fine sand, medium sand	Yes		
F85	100.10	Loess-like soil, silty clay, medium sand, gravelly sand			
F86	100.20	Silty clay, fine sand, medium sand	Yes		
F87	150.00	Silty clay, fine sand, medium sand, gravelly sand, sandy gravel layer	Yes		Soil sample
F88	100.20	Loess-like soil, silty clay, medium sand, coarse sand, gravelly sand	Yes		
F89	100.20	Silty clay, fine sand, medium sand, coarse sand	Yes		
F90	150.00	Silty clay, fine sand, medium sand, coarse sand	Yes	Yes	Soil sample
F91	100.00	Silty clay, fine sand, medium sand	Yes		Soil sample
F92	100.00	Silty clay, medium sand	Yes	Yes	Soil sample
F93	150.40	Silty clay, fine sand, medium sand, coarse sand, sandy gravel layer	Yes		
F95	100.20	Silty clay, fine sand, medium sand	Yes		
F96	150.30	Silty clay, fine sand, medium sand, coarse sand	Yes		
F97	100.50	Loess-like soil, silty clay, medium sand, coarse sand	Yes		
F98	100.50	Silty clay, fine sand, medium sand, coarse sand	Yes		
F99	100.10	Silty clay, fine sand, medium sand, coarse sand	Yes		
F100	100.10	Silty clay, medium sand, coarse sand	Yes		
F101	100.00	Silty clay, fine sand, medium sand	Yes		Soil sample

Continued table 2

Borehole No.	Borehole depth/m	Lithology recorded	Logging	MWD	Testing
F102	100.00	Silty clay, fine sand, medium sand	Yes		
F103	100.20	Silty clay, fine sand, medium sand	Yes		
F104	150.00	Silty clay, fine sand, medium sand	Yes	Yes	Soil sample
F105	100.40	Silty clay, fine sand, medium sand, coarse sand	Yes	Yes	
F106	100.00	Loess-like soil, silty clay, fine sand, medium sand, coarse sand	Yes		Soil sample

Table 3 Basic Information of Engineering Geological Boreholes in Yan'an

Borehole No.	Borehole depth/m	Lithology recorded	Logging	MWD	Testing
ZK01	52.30	Silty clay, sandy gravel layer, fine sandstone, mudstone			
ZK02	192.86	Silty clay, sandy gravel layer, fine sandstone, mudstone, coarse sandstone	Yes	Yes	Core sample
ZK03	272.68	Silty clay, sandy gravel layer, fine sandstone, mudstone, coarse sandstone	Yes	Yes	Core sample
ZK04	293.00	Fine sandstone, mudstone, coarse sandstone	Yes	Yes	
ZK05	214.00	Fine sandstone, mudstone, coarse sandstone	Yes		Core sample
ZK06	139.00	Sandy gravel layer, fine sandstone, mudstone	Yes	Yes	Core sample
ZK07	202.00	Fine sandstone, mudstone, coarse sandstone	Yes	Yes	
ZK08	56.80	Silty clay, sandy gravel layer, fine sandstone, mudstone			
ZK09	151.00	Loess, fine sandstone, mudstone, coarse sandstone	Yes		
ZK10	119.50	Fine sandstone, mudstone, coarse sandstone			
ZK12	102.00	Silty clay, sandy gravel layer, fine sandstone, mudstone, coarse sandstone		Yes	
ZK13	92.00	Silty clay, fine sand, sandy gravel layer, fine sandstone, mudstone, coarse sandstone			Core sample
ZK14	90.00	Loess, red clay, fine sandstone, mudstone	Yes		Soil sample
ZK15	99.00	Fine sandstone, mudstone, coarse sandstone	Yes		Core sample
ZK16	130.00	Fine sandstone, mudstone, coarse sandstone			Core sample
ZK17	174.00	Fine sandstone, mudstone, coarse sandstone	Yes		Core sample
ZK18	92.00	Fine sandstone, mudstone, coarse sandstone			
ZK19	120.00	Loess, red clay, coarse sandstone		Yes	
ZK21	118.00	Fine sandstone, mudstone, coarse sandstone	Yes		
ZK22	98.00	Loess, fine sandstone, mudstone, coarse sandstone	Yes		
ZK23	173.00	Red clay, fine sandstone, mudstone, coarse sandstone	Yes		
ZK24	104.00	Loess			Soil sample
ZK25	89.00	Loess, red clay			
ZK26	64.00	Loess, red clay, fine sandstone, mudstone			Soil sample
ZK27	123.00	Loess			Soil sample
ZK28	108.00	Loess, red clay, fine sandstone, mudstone			Soil sample
ZKP2-1	126.80	Loess, red clay, fine sandstone, mudstone			
ZKP2-2	75.40	Red clay, fine sandstone, mudstone			
ZKP2-3	50.00	Loess, fine sandstone, mudstone, coarse sandstone			
ZKP3-1	117.00	Loess, red clay			Soil sample
ZKP3-2	110.00	Loess, red clay, fine sandstone, mudstone			Soil sample
ZKP3-3	131.50	Loess, red clay			Soil sample

Table 4　Basic information of Engineering Geological Boreholes in Shanyang

Borehole No.	Borehole depth/m	Lithology recorded	Logging	MWD	Testing
Shanyang Middle School ZK1	20.00	Clay, coarse sand, sandy gravel layer		Yes	
Shanyang Middle School ZK3	20.00	Clay, coarse sand, sandy gravel layer		Yes	
Shanyang Middle School ZK4	20.00	Silty clay, clay, calcareous nodule		Yes	
Shanyang Middle School ZK5	20.00	Clay, medium sand, coarse sand, sandy gravel layer		Yes	
Qiaoergou ZK2	20.00	Diluvium layer, phyllite		Yes	
Qiaoergou ZK3	34.00	Diluvium caused by landslide, phyllite		Yes	
Qiaoergou ZK4	20.00	Diluvium layer, phyllite		Yes	
Qiaoergou ZK5	20.00	Diluvium layer, phyllite		Yes	

Table 5　Conditions Used to Determine Effective MWD Data During Extraction from Initial Drilling Data

	Drilling rig state	Displacement sensor C	Rotational speed sensor R	Oil pressure sensor P
Drilling progresses	Pressurized drilling	$C2-C1<a$	$R>0$	$P1>P2$
	Non-pressurized drilling	$C2-C1=0$	$R>0$	$P1=P2=0$
Other processes	Hollow drilling	$C2-C1>a$	$R>0$	$P1>P2$
	Remove drilling rod, install drilling rod	$C2-C1=0$	$R=0$	$P1<P2$

Notes: $P1$ and $P2$ refers to upper oil pressure and lower oil pressure, respectively. a refers to the value determined based on the MWD data and drilling records and it differs between drilling in rocks and drilling in soils.

Table 6　Basic Information of the Urban Underground Space Exploration in Xi'an

No.	Method	Measuring date	Workload	Sampling interval/m
1	Multi-parameter comprehensive logging	September 11–21	200 m	0.05
2	Microtremor array method	October 11–14	16 points	100
3	High-density resistivity method	October 19–22	2.01 km	7
4	Shallow seismic prospecting	October 14–28	1.8 km	4
5	Geological radar method	October 23–26	2.8 km	1
6	High-density resistivity method	November 8–11	2.04 km	5

parameters such as density, porosity and permeability. The strength of rocks or soil can be calculated with acoustic interval transit time and density. The borehole data and their file formats are shown in Table 8. As an example, the statistics of the logging results from the engineering geological boreholes drilled in Yan'an is shown in Table 9.

The characteristics of the borehole logging curve of the Yan'an Formation can be seen in Fig. 7. The values of the average strength index of the boreholes drilled in Yan' an were obtained by calculating and analyzing the acoustic logging data of these boreholes (Fig. 8). It can be identified from the isoline map that the maximum of the average strength index is 26.69 MPa, corresponding to the borehole ZK04, and the minimum is 19.89 MPa, corresponding to the borehole ZK02, with a general average strength index ranging from 30–15 MPa. Therefore,

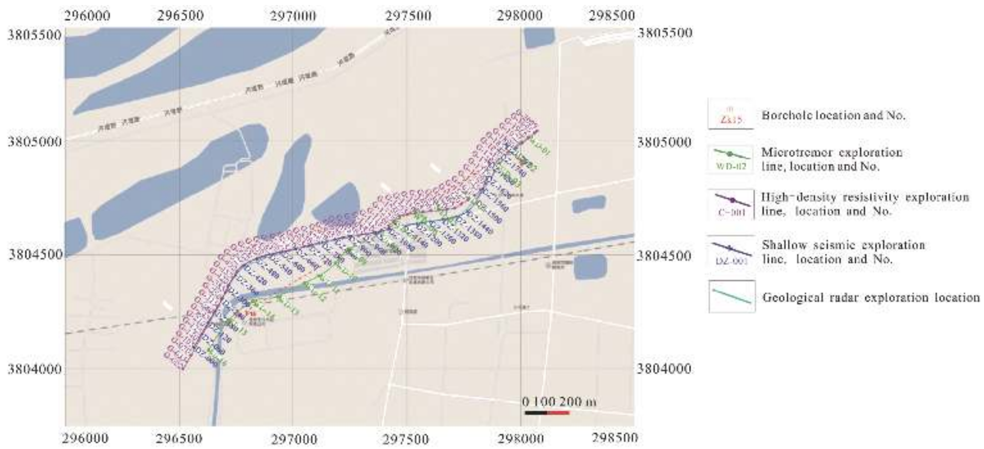


Fig. 5 Scheme of refined exploration of urban underground space in Xi'an

Table 7 Engineering Geological Borehole Data and Their File Formats

Data name	File format
Stratigraphic Column of the Boreholes in Xi'an	.dwg (CAD file)
Stratigraphic Column of the Boreholes in Yan'an	.mpj (MapGIS file)

the engineering geological rock masses of Yan'an belong to soft socks.

3.3 Monitoring-While-Drilling (MWD)

The data obtained from MWD include drilling parameters such as borehole depth, drill rod displacement, rotational speed of drill rod and oil pressure. The MWD data and their file formats are shown in Table 10.

It can be observed from the MWD results (Fig. 9) of the borehole ZK07 drilled in the Yan' an working area that the drilling speed varies with different strata. For instance, in the Fuxian Formation, the mudstone was drilled at a higher speed than the fine-grained sandstone. Furthermore, the drilling speed also differs in sandstone and mudstone of different ages. For example, the sandstone and mudstone of the Fuxian Formation were drilled at a higher speed than that of the Wayaobu Formation.

It can be observed from the MWD results (Fig. 10) of the borehole ZK19 drilled in Yan' an working area that the drilling speed varies with different strata. For example, the drilling speed in loess is higher than that in strongly weathered sandstone and mudstone. Moreover, the drilling speed varies with different ages in the loess. In detail, the earlier the loess age, the lower the drilling speed.

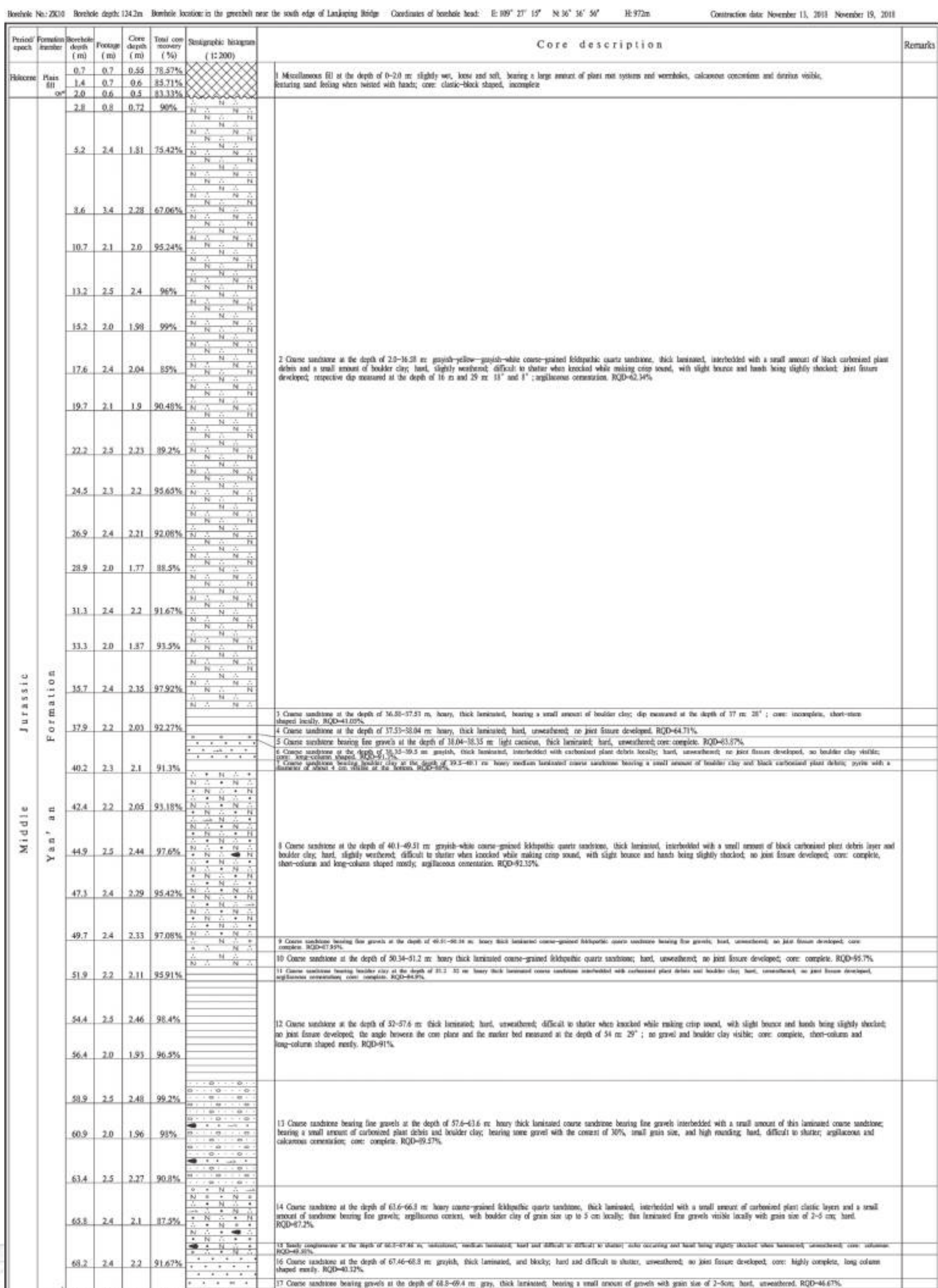
3.4 Testing

The testing data were obtained from the core samples and soil samples. The former includes sampling horizon, compressive strength, elastic modulus and cohesion, and the later includes sampling horizon, moisture content, pore ratio, coefficient of collapsibility and cohesion. All the data are in the format of .xls. The statistics of the test results of the physical and mechanical indices of the soil samples and cores taken from the boreholes in Yan' an are shown in Tables 11–13.

3.5 Ground Geophysical Exploration

The seismic velocity, resistivity, radar and seismic reflection profiles were developed by processing the data obtained by the microtremor array method, high-density resistivity method, geological radar method and shallow seismic prospecting respectively. The folders of the geophysical prospecting data contain the measuring line distribution maps, technical explanations, working reports and comprehensive profiles.

The data obtained from ground geophysical prospecting include depth, apparent resistivity, reflection records of the geological radar method, reflection records of the shallow seismic prospecting and records of the microtremor array method. The initial data obtained



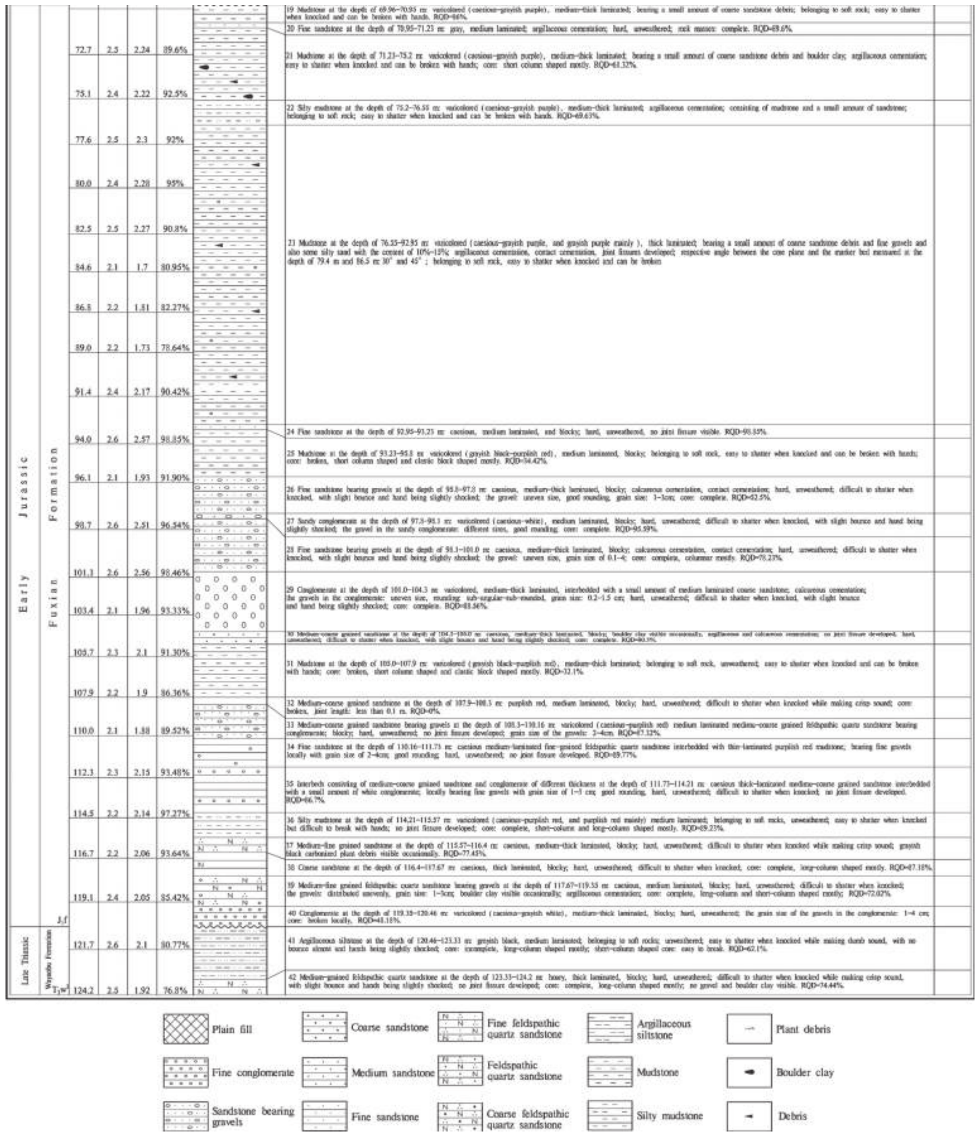


Fig. 6 The Comprehensive Stratigraphic Column of the ZK10 in Yan'an Work Area

Table 8 Logging Data of Boreholes and Their File Formats

Data name	File format
Initial data	.txt
Logging curve, comparison diagram	.mpj (Mapgis file)
Isoline map	.jpg
Summary of logging of single boreholes	.doc
Technical description, report	.doc, .pdf

from each method were in different formats and were all analyzed with professional software. As a result, corresponding resistivity, geological radar, seismic reflection and transverse wave velocity profiles were achieved. Furthermore, these profiles were concentrated and compared with borehole data and were then saved as .jpg files. The results of the refined exploration of urban underground space in Xi'an are shown in Fig. 11, which contains the profiles obtained from the high-density resistivity method, shallow seismic prospecting and the microtremor

Table 9 Statistics of Logging Results from Engineering Geological Boreholes in Yan’an

Horizon	Lithology	Apparent resistivity/Ω.m	Density/ (g/cm^3)	Natural gamma ray/*API*	Porosity/ %	Permeability/ md^{-1}
		Average	Average	Average	Average	Average
Quaternary (Q)	Silty clay	60.08	2.13	111.48	10.11	13.36
	Silty soil	108.12	1.95	109.62	18.58	12.40
	Silty sand	21.60	2.10	92.40	10.01	12.02
	Fine sand	108.04	2.03	81.30	10.96	11.24
	Gravel	136.23	2.48	54.30	15.22	12.25
	Loess	140.16	1.98	113.04	16.99	15.16
J_2y^2	Sandy mudstone	33.62	2.26	121.58	8.41	10.59
	Fine-grained sandstone	40.74	2.28	106.31	6.13	12.62
	Mudstone	21.50	2.37	167.82	7.50	13.52
	Medium-grained sandstone	33.62	2.26	121.58	8.41	10.59
	Siltstone	31.84	2.40	130.50	7.00	11.24
	Fine conglomerate	37.56	2.21	82.81	9.20	10.25
	Coarse-grained sandstone	42.39	2.07	56.56	10.26	9.56
J_2y^1	Sandy mudstone	31.53	2.26	155.29	8.38	10.93
	Mudstone	21.22	2.33	160.82	9.60	10.15
	Coarse-grained sandstone	78.45	2.33	58.15	9.82	9.57
	Fine-grained sandstone	60.81	2.30	93.72	9.24	10.18
	Medium-grained sandstone	49.47	2.31	79.19	9.27	10.60
	Siltstone	46.29	2.46	103.01	13.25	11.34
	Fine conglomerate	226.96	2.41	43.20	13.10	11.24
	Medium conglomerate	53.86	2.44	85.37	7.42	11.17
J_2f	Mudstone	15.32	2.43	173.38	8.31	11.42
	Sandy mudstone	26.88	2.41	130.50	6.22	10.81
	Coarse-grained sandstone	28.08	2.49	60.62	14.62	9.61
	Fine-grained sandstone	25.36	2.49	118.32	12.62	10.53
	Medium-grained sandstone	35.36	2.37	106.68	11.15	9.84
	Siltstone	31.12	2.51	143.58	9.05	9.55
T_3w	Mudstone	26.29	2.46	184.23	10.82	10.08
	Sandy mudstone	41.05	2.45	163.14	9.73	9.78
	Medium-grained sandstone	60.75	2.50	82.99	13.04	9.50
	Fine-grained sandstone	67.70	2.49	110.10	12.83	10.65
	Carbonaceous mudstone	25.53	1.93	178.53	9.26	9.53
	Argillaceous siltstone	42.91	2.45	164.40	8.53	9.83

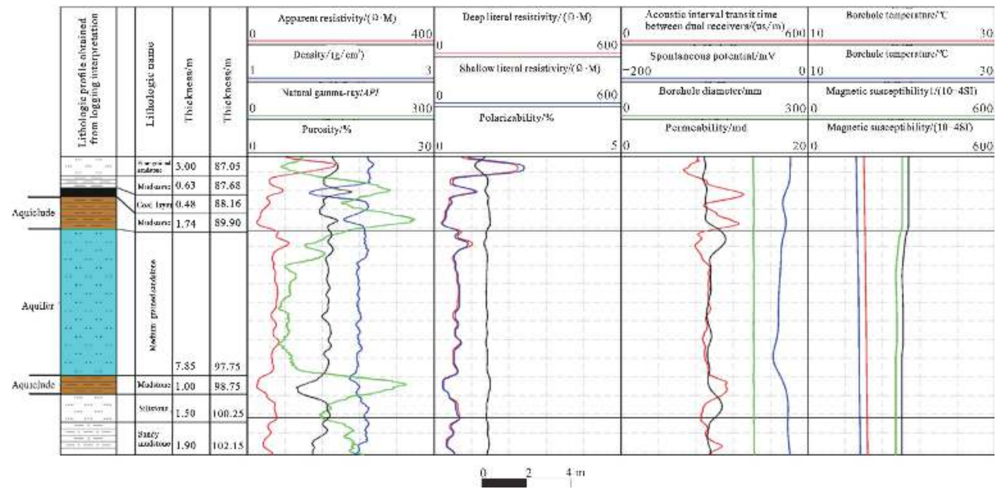


Fig. 7 Characteristics of the Logging Curve of Engineering Geological Boreholes Drilled in the Yan'an Formation

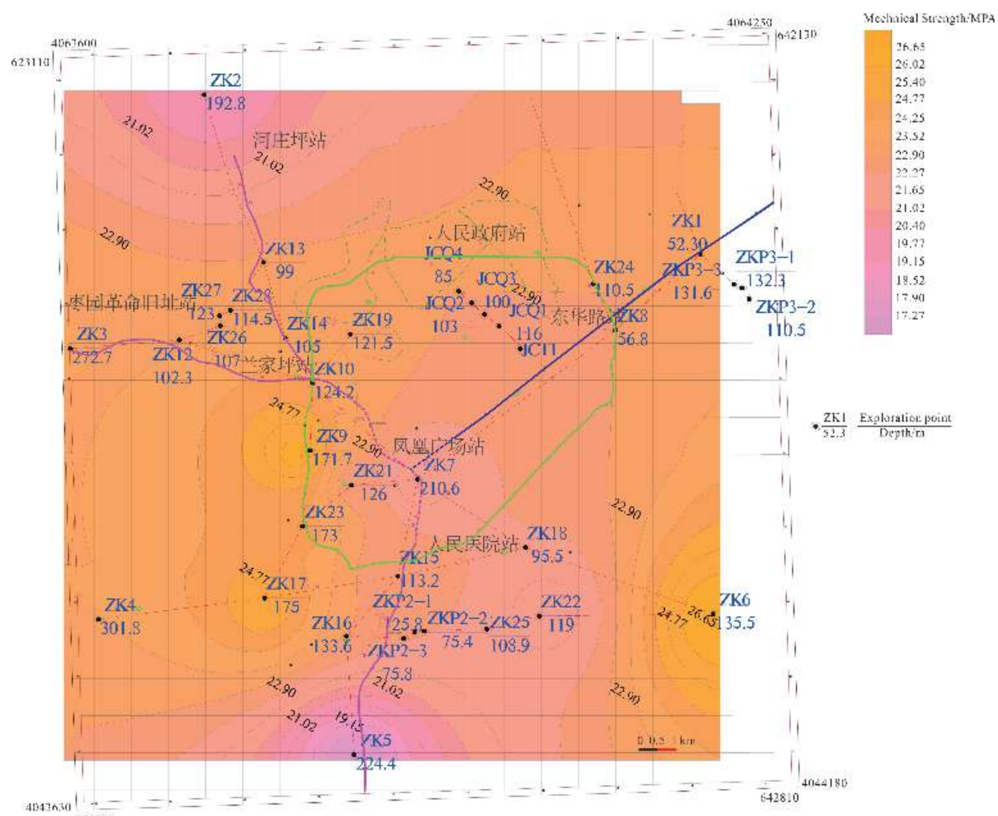


Fig. 8 Stratigraphic Mechanical Strength Isoline Map of the Yan'an Working Area

Table 10 MWD Data and Their File Formats

Data name	File format
Initial data	.txt
Analytical result	.xls
MWD parameter curve	.srf (surfer file)
Technical manual, report	.doc

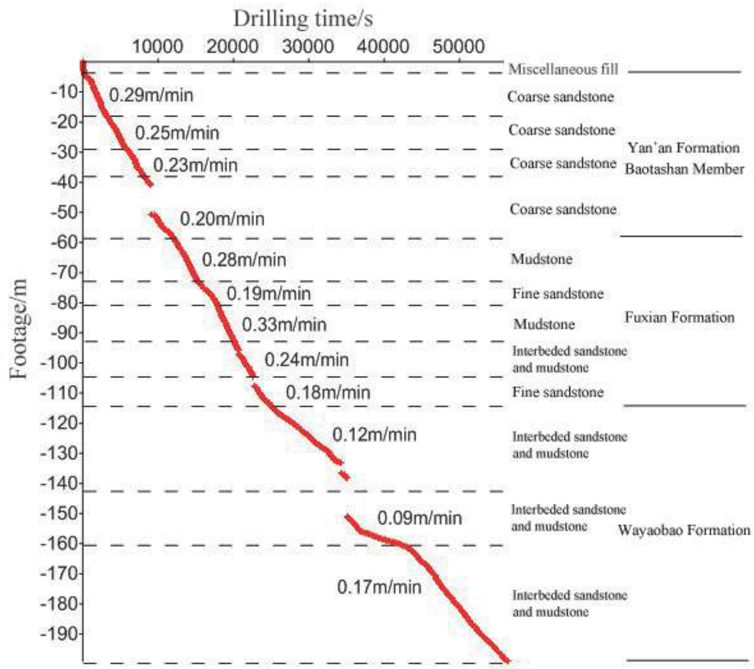


Fig. 9 MWD Result Curve and Stratigraphic Comparison of the Borehole ZK07 in Yan'an

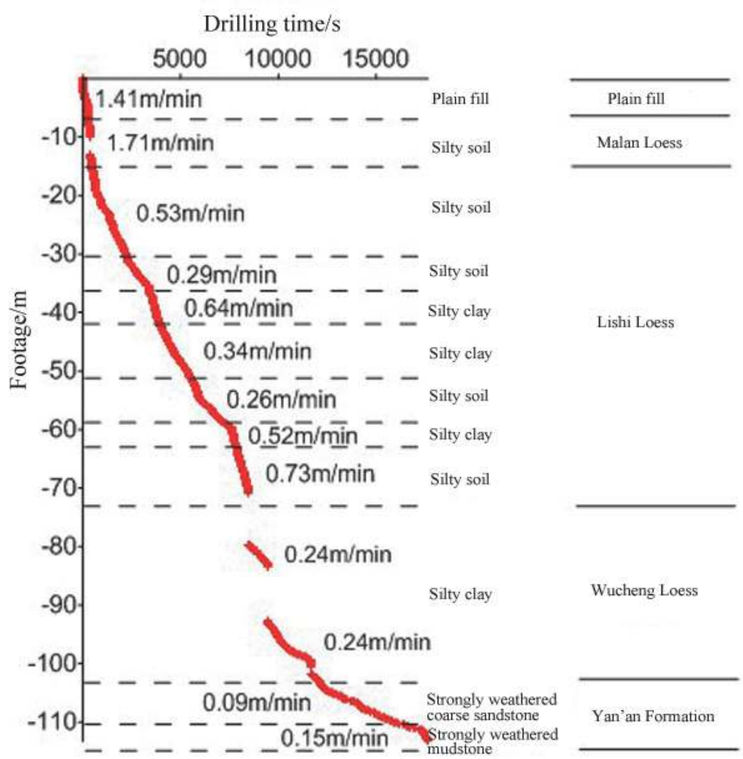


Fig. 10 MWD result curve and stratigraphic comparison of the borehole ZK19 in Yan'an

array method.

Based on multi-parameter geophysical logging data as well as the data of geophysical prospecting, the strata of urban underground space in Xi'an are as follows, according to the comprehensive interpretation of the profiles.

Member at the depth of 0.00–17.40 m: interbeds consisting of fine, medium, silty and

Table 11 Statistics of Test Results of the Physical and Mechanical Indices of the Loess and Red Clay in Yan'an

Layer No.	Value type	Moisture content/%	Unit weight /kN.m^{-3}	Dry unit weight /kN.m^{-3}	Pore ratio	Degree of saturation/ %	Liquid limit/%	Plastic limit/%	Plastic index/%	Liquidity index/%	Compression coefficient / MPa^{-1}	Coefficient of collapsibility	Cohesion /kPa	Inner friction angle/°
Late Pleistocene loess	Statistic frequency	30	29	29	29	29	30	30	30	30	29	15	8	8
	Max.	20.2	19	16.8	1.31	76.0	28.2	17.5	11.0	0.72	0.2	0.099	62.1	32.2
	Min.	3.0	13.3	12.4	0.61	15.0	24.6	16.7	9.4	<0	0.1	0.030	22.1	15.3
	Mean	12.72	15.9	14.1	0.94	38.86	27.13	17.15	9.89		0.19	0.075	33.54	24.1
	Standard deviation	4.77	1.6	1.1	0.16	17.0	0.47	0.12	0.3		0.08		13.33	5.31
	Coefficient of variation	0.38	0.10	0.08	0.17	0.44	0.02	0.01	0.04		0.44		0.40	0.22
Middle Pleistocene loess	Statistic frequency	127	127	127	127	127	126	128	128	129	126	12	60	60
	Max.	22.6	21.0	18.1	0.987	98.0	29.9	17.9	12.0	0.92	0.46	0.078	75.8	45.0
	Min.	4.9	16.8	13.8	0.482	38.0	24.3	16.6	7.7	0.0	0.07	0.004	10.8	13.6
	Mean	18.39	19.0	16.0	0.7	71.94	29.16	17.46	11.7	0.17	0.13	0.013	45.41	29.81
	Standard deviation	3.73	0.9	0.8	0.09	12.9	1.91	0.74	0.24	0.20	0.06		19.33	7.06
	Coefficient of variation	0.20	0.05	0.05	0.12	0.18	0.07	0.04	0.11	1.19	0.43		0.43	0.24
Red clay	Statistic frequency	4	4	3	4	3	4	4	4	4	4	4	4	4
	Max.	17.60	20.9	18.8	0.618	91.6	30.7	21.2	11.7	0.71	0.12	0.005	450.8	54.5
	Min.	7.07	17.5	17.8	0.443	66.9	25.9	16.8	9.1	0.57	0.02	0.002	41.65	24.0
	Mean	11.99	19.2	18.2	0.517	75.56	29.03	18.9	10.2	0.67	0.08	0.003	201.8	32.4

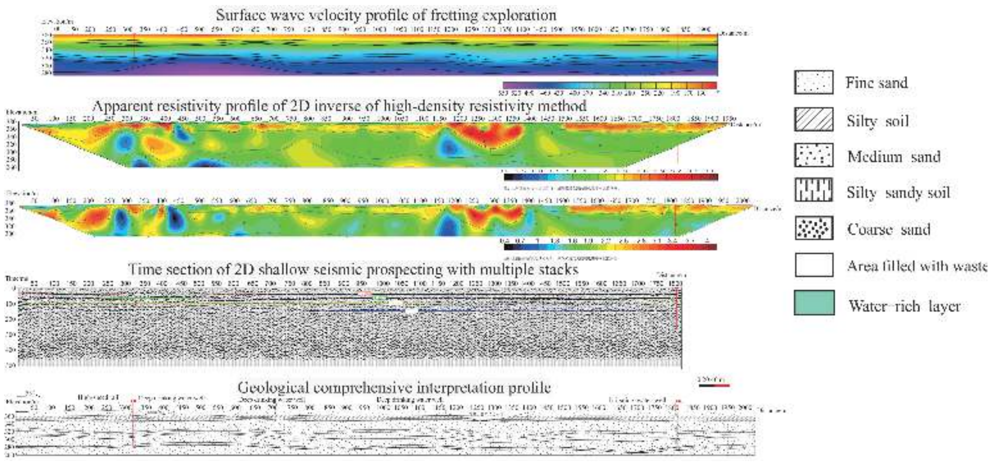


Fig. 11 Comprehensive profiles of underground space exploration in Xi'an and interpretation results

Table 12 Statistics of Test Results of Physical and Mechanical Indices of Sandstone in Yan'an

Statistic index		Statistic number	Max.	Min.	Mean	Standard deviation	Coefficient of variation
Saturated unit weight/g.cm^{-3}		36	2.72	2.66	2.68	0.02	0.01
Specific gravity		36	2.54	2.23	2.31	0.09	0.03
Normal water absorption		36	6.92	6.26	6.53	0.22	0.03
Softening coefficient		36	0.72	0.57	0.67	0.05	0.11
Tensile strength/MPa		36	2.4	1.5	1.97	0.28	0.14
Uniaxial compressive strength/MPa	Dry	36	75.1	43.0	61.2	10.9	0.20
	Water saturated	36	51.3	28.2	41.2	9.07	0.22
Elastic modulus/MPa		36	4583	3865	4203	233.4	0.10
Poisson's ratio		36	0.26	0.17	0.22	0.03	0.12
Cohesion/MPa		36	4.6	3.9	4.23	0.24	0.10
Inner friction angle/°		36	43.5	40.0	41.6	1.00	0.02

Table 13 Statistics of Test Results of Physical and Mechanical Indices of Mudstone in Yan'an

Statistic index		Statistic number	Max.	Min.	Mean	Standard deviation	Coefficient of variation
Uniaxial compressive strength/MPa	Dry	33	1.336	0.747	0.944	0.15	0.16
	Water saturated	33	0.774	0.311	0.502	0.16	0.31
Elastic modulus/MPa		33	9.8	6.86	7.26	2.08	0.25
Poisson's ratio		33	0.30	0.25	0.26	0.04	0.13
Cohesion/kPa		33	71.1	16.7	53.85	3.8	0.21
Inner friction angle/°		33	35	21	26	1.0	0.16

coarse sand. This member features high resistivity, negatively abnormal spontaneous potential, and low acoustic wave speed. Therefore, it can be inferred that this member is medium dense. Additionally, the part at the depth of 9.35–17.40 m is a weak aquifer.

Member at the depth of 17.40–19.35 m: silty clay. This member features low resistivity, slightly high acoustic-wave speed and spontaneous potential without any significant anomalies. Therefore, it can be inferred that this member is dense.

Member at the depth of 19.35–73.10 m: interbeds consisting of medium sand and fine sand, sandwiched with rounded gravels. This member features high resistivity and slightly high acoustic-wave speed. Therefore, it can be inferred that this member is dense.

Member at the depth of 73.10–76.50 m: silty clay interbedded with medium sand. This member features low resistivity locally, slightly high acoustic-wave speed and spontaneous potential without any significant anomalies. Therefore, it can be inferred that this member is dense.

Member at the depth of 76.50–84.85 m: medium sand. This member is a strong aquifer and features medium – low resistivity, high acoustic-wave speed and negative abnormal spontaneous potential. Therefore, it can be inferred that this member is hard with uniform particle size but large porosity.

Member at the depth of 84.85–87.55 m: silty clay interbedded with fine sand. This member features low resistivity and slightly high acoustic-wave speed. Therefore, it can be inferred that this member is dense.

Member at the depth of 87.55–95.00 m: fine and medium sands are interbedded with each other, medium resistivity, higher acoustic-wave speed and spontaneous potential without any discernable anomalies. Therefore, it can be inferred that this member is dense.

Member at the depth of 95.00–124.00 m: medium sand. This member features low – medium resistivity, high acoustic-wave speed and spontaneous potential without any distinct anomalies. Therefore, it can be inferred that this member is dense.

4 Data Quality Control and Assessment

The engineering geological drilling, sampling and testing were carried out in accordance with DZ/T 0017−1991 *Specifications for Engineering Geological Drilling*, GB/T 50123−1999 *Standard for Geotechnical Test Methods*, GB 50021−2009 *Code for Investigation of Geotechnical Engineering* and DD 2019−06 *Technical Specifications for Engineering Geological Survey (1 : 50 000)*. All relevant information was recorded into data tables and checked daily. Multi-parameter logging was conducted according to applicable specifications (DZ/T 0181−1997 *Specifications for Hydrological Logging*). The urban underground space was explored with proper geophysical methods. All the methods were implemented in accordance with applicable specifications (CJJ 7−2007 *Code for Engineering Geophysical Prospecting and Testing in City*) and relevant data were processed by professional staff. Since MWD technology is currently not well developed, and so there are no related specifications available. However, the data acquisition and processing of MWD was conducted according to existing research results.

5 Value of the Data

Influenced by the physical field with strong interference, complex geological environmental conditions and existing city buildings, there is still neither any mature theory on or any developed technology for urban underground space exploration. Meanwhile, traditional methods and the current geological survey fail to fully satisfy the demand for the assessment and development and utilization planning of urban underground space resources. Therefore, during the development of the Dataset, MWD technology was introduced in loose Quaternary sediment strata and 13 parameters including natural gamma-ray, spontaneous potential, density, acoustic interval transit time, dual laterolog resistivity, polarizability, magnetic susceptibility, gamma-ray spectrometry and well temperature, diameter and deviation were selected for in-hole geophysical prospecting. In this way, a combined method of underground space exploration that overcomes strong interference was established; since it integrates drilling with MWD, ground geophysical prospecting with in-hole geophysical prospecting and in-situ tests with indoor tests; with the added benefit of obtaining valuable data. Furthermore, the working areas of the Dataset cover the Qinba Mountains, the Guanzhong Basin, and the Loess Plateau in Shaanxi Province and, therefore, the data in the Dataset is typical. The data obtained is vital for the quality assessment of rock and soil masses, the establishment of 3D all-element urban geological models, the assessment of underground space resources, the research on the coupling relationship between the quality and physical properties of rock and soil masses and the practice and scientific research of urban geology and geotechnical engineering.

6 Conclusion

The Dataset covers the Qinling Mountains, the Guanzhong Basin, and the Loess Plateau in Shaanxi Province. It consists of five folders that are used to store the geotechnical drilling, testing, multi-parameter logging, MWD and ground geophysical prospecting data. In detail, the data involves 144 engineering geological boreholes, 672 testing samples, 111 boreholes for the geophysical prospecting of 13 parameters, 36 MWD boreholes, 5 profiles of ground geophysical prospecting via 4 methods. In total, the Dataset consists of 968 sets of data and 3 664 files in the format of .jpg, .xls, .doc, .mpj and .dwg.

The data of boreholes include drilling date, borehole depth, stratigraphic lithologic description, sub-layer No., sub-layer depth and sampling depth; the data of logging include natural gamma-ray, spontaneous potential, density, acoustic interval transit time, dual laterolog resistivity, polarizability, magnetic susceptibility, gamma-ray spectrometry, the well temperature, diameter and deviation; the data of MWD include measuring date, drilling roundtrip, length of added drill rod, borehole depth, cylinder displacement, rotational speed of drill rod, oil pressure and torsion pressure. The data obtained from testing consist of core and soil sample data. The former includes moisture content, natural density, cohesion, inner friction angle, coefficient of self-weight collapsibility and specific surface area and the later includes acoustic velocity and uniaxial compressive strength. The data of ground geophysical prospecting include prospecting method, collating unit, number of measuring points, length of measuring line and sampling interval. This Dataset can be applied to the quality assessment of rock and soil masses, the establishment of 3D urban geological all-element models, the assessment of underground space resources, the research on the coupling relationship between the quality and physical-property-related parameters of rock and soil masses and the practice and scientific research of urban geology and geotechnical engineering.

During the geological survey of the Dataset, a combination of multi-parameter exploration technologies for urban geology and underground space with strong interference has been gradually established and a wealth of valuable data has been accumulated. In view of our limited energy and capabilities and also the public-welfare-oriented requirements of geological work, we provide all the data and information to the public, without any reservation, for the purpose of data sharing, in hope that the experts and scholars at home and abroad will study them cooperatively.

Acknowledgments: We would like to extend our sincere appreciation to Professor Yue Zhongqi and Senior Technician Chen Dijiu from the University of Hong Kong, Associate Professor Gu Tianfeng from the Northwest University and Associate Professor Zhang Zhongjian from the China University of Geosciences (Beijing) for their strong support on technologies, methods and monitoring instruments of MWD. We would also like to thank President Liu Xianbin and Deputy Chief Engineer Zhou Xiaoyan from the Shaanxi Institute of Engineering Prospecting Co., Ltd., President Wang Hui from the Aerial Photogrammetry and Remote Sensing Bureau, China National Administration of Coal Geology and the leader of the Dataset development Guo Ruihua for their organization of the implementation of the main engineering geological drilling. Our sincere appreciation also goes to Deputy General Managers, Liu Jianli and Yu Changzhong, from the Shaanxi Geology and Mining Geophysical and Geochemical Prospecting Team Co., Ltd. for their organization of the implementation of geophysical prospecting. Lastly, our thanks go to the peer reviewers and the editors for their valuable opinions on the revision of this paper.

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