Prepared in cooperation with the Afghanistan Geological Survey under the auspices of the
U.S. Agency for International Development

Preliminary Non-Fuel Mineral Resource Assessment of
Afghanistan


USGS Open-File Report 2007–1214
USGS Afghanistan Project Product No. 157

*Stephen G. Peters\(^1\) (Team Leader), Stephen D. Ludington\(^2\), Greta J. Orris\(^3\), David M. Sutphin\(^1\), James D. Bliss\(^3\), James J. Rytuba\(^2\), Jared Abraham\(^4\), Mohammad Bashir\(^5\), Robert G. Bohannon\(^4\), Karen Sue Bolm\(^4\), Jeff L. Doebrich\(^1\), Robert G. Eppinger\(^4\), Carol A. Finn\(^4\), Bernard E. Hubbard\(^1\), Bruce R. Lipin\(^1\), Walter J. Bawiec\(^1\), Keith R. Long\(^1\), John C. Mars\(^4\), Mohammad Saleh\(^5\), Lawrence W. Snee\(^5\), Douglas B. Stoeser\(^4\), Cliff D. Taylor\(^4\), Mohammad Omar Younusi\(^1\), Mohammad Asif Yousof\(^5\), Abdul Wasy\(^5\), and Gulraihan Waziri\(^5\).


U.S. Department of the Interior
U.S. Geological Survey
**Contents**

Summary ............................................................................................................................................................................. xxviii

1.0 Introduction ........................................................................................................................................................................ 1
  1.1 Background ........................................................................................................................................................................ 1
  1.2 Past Development ................................................................................................................................................................. 2
  1.3 Assessment Methods ......................................................................................................................................................... 3
  1.4 Geologic History ................................................................................................................................................................. 11
  1.5 Metallogeny .......................................................................................................................................................................... 13
  1.6 Acknowledgements .............................................................................................................................................................. 17

2.0 Deposits related to mafic igneous rocks ......................................................................................................................... 21
  2.1 Podiform Chromite .............................................................................................................................................................. 21
    2.1.1 Chromite Mineral Occurrences ....................................................................................................................................... 21
    2.1.2 Description of Podiform Chromite Deposit Models ........................................................................................................ 21
      Previous Investigations .......................................................................................................................................................... 22
      Logar Province ................................................................................................................................................................. 23
    2.1.3 Description of Mineral-Resource Tracts and Areas of Interest .................................................................................... 25
      Tract ID: umf01A—Eocene Ultramafic Rocks of Logar Valley .......................................................................................... 25
      Parwan province ............................................................................................................................................................... 32
      Tract ID: umf01B—Eocene Ultramafic Rocks Near Khost ................................................................................................. 37
      Area ID: umf01C—Eocene Ultramafic Rocks of Paktia, Province, North of Khost, Area of Interest ............................................ 43
      Area ID: umf01D—Ghazni to Kandahar Valley Area of Interest ............................................................................................ 44
    Additional Areas of Interest of Ultramafic-Hosted Mineral Deposits ..................................................................................... 46
      Area ID: umf02—Proterozoic Ultramafic Rock Area of Interest .......................................................................................... 46
      Area ID: umf03—Paleozoic Ultramafic Rocks Area of Interest .............................................................................................. 47
      Area ID: umf04—Mesozoic Ultramafic Rocks Area of Interest .............................................................................................. 48
  2.2 Ultramafic-Hosted Talc-Magnesite ................................................................................................................................. 52
    2.2.1 Talc-Magnesite Deposit Models ..................................................................................................................................... 52
      Tract ID: umf01A—Eocene Age Ultramafic Rocks of Logar Valley ....................................................................................... 57
      Tract ID: umf01B—Eocene Age Mafic and Ultramafic Rocks of the Khost Area .................................................................. 61
  2.3 Serpentine-Hosted Asbestos .............................................................................................................................................. 66
    Health concerns ....................................................................................................................................................................... 66
    2.3.1 Serpentine-Hosted Asbestos Deposit Models ................................................................................................................ 67
      Mineral Resource Tracts and Areas of Interest .................................................................................................................... 73
      Tract ID: umf01A—Eocene Age Ultramafic Rocks of Logar Valley ....................................................................................... 73
      Tract ID: umf01B—Eocene Age Mafic and Ultramafic Rocks of the Khost Area ................................................................ 78
    2.3.2 Description of tracts for Older Serpentine-Hosted Asbestos and Ultramafic-Hosted Talc-Magnesite ......................... 82
      Tract ID: mir01—Asbestos, magnesite, and talc in Proterozoic age mafic and ultramafic intrusive rocks ........................................ 83
      Tract ID: mir02—Asbestos, magnesite, and talc Mississippian (Lower Carboniferous) and Permian age mafic and ultramafic intrusive rocks ...................................................................................................................... 85
3.0 Deposits related to alkaline intrusions ................................................................. 95
  3.1 Carbonatite (U-Th-REE-apatite) ........................................................................ 95
    3.1.1 Descriptive model of carbonatite (U-Th-REE-apatite) .................................... 95
  3.2 Carbonatite (U-Th-REE-apatite) Tract Descriptions ........................................ 96

4.0 Deposits related to felsic phanerocrystalline intrusive rocks ............................. 106
  4.1 Tin and tungsten deposits .................................................................................. 106
    4.1.1 Descriptive models for tin and tungsten deposits .......................................... 107
    4.1.2 Tract Descriptions ....................................................................................... 108
  4.2 Sedimentary rock-hosted fluorite (fluorspar) ..................................................... 118
    4.2.1 Fluorite vein deposit model .......................................................................... 118
    4.2.2 Fluorite Tract Description ........................................................................... 118
    Permissive tract fluor01—Bakhud ........................................................................ 118
  4.3 Pegmatites ......................................................................................................... 123
    4.3.1 Description of pegmatite deposit models ...................................................... 123
    4.3.2 Pegmatite Mineral-Resource Tract ............................................................... 127

5.0 Deposits related to felsic to intermediate porphyritic igneous rocks ................. 129
  5.1 Porphyry copper and associated deposits ....................................................... 129
    5.1.1 Descriptive Models .................................................................................... 130
      5.1.2 Tract Descriptions .................................................................................. 133
        Chagai east tract (ppycu01) ............................................................................ 135
        Chagai west tract (ppycu02) .......................................................................... 140
        Spin Boldak tract (ppycu03) ........................................................................ 145
        Saindak north tract (ppycu04) ..................................................................... 150
        Kundalyan-Zarkhashan tract (ppycu05) ........................................................ 155
        Arghandab tract (ppycu06) .......................................................................... 163
        Katawaz tract (ppycu07) ............................................................................. 168
        Feroz Koh tract (ppycu08) .......................................................................... 172
        Farah Rod tract (ppycu09) .......................................................................... 177
        West Hindu Kush tract (ppycu10) ................................................................. 182
        West Badakhshan tract (ppycu11) ................................................................. 187
        Helmand tract (ppycu12) ............................................................................ 188
  5.2 Pluton-related gold deposits .............................................................................. 194
    5.2.1 Description of tracts for pluton-related gold deposits .................................. 195
      Permissive tract—gold03 Kandahar-Zabul-Ghanzi gold ................................. 195
Favorable tract gold03-f1 ........................................................................................................................................197
Prospective tract gold03-p1-Kundalyan-gold ........................................................................................................197
Prospective tract gold03-p2 ....................................................................................................................................197
Favorable tract gold03-f2 ........................................................................................................................................201
Prospective tract gold03-p3 Bolo gold ..................................................................................................................201
Prospective tract gold03-p3 Dynamic ....................................................................................................................201

6.0 Deposits related to felsic to intermediate extrusive rocks ........................................................................ 208
6.1 Mercury deposits ...........................................................................................................................................208
   6.1.1 Descriptive Models for Epithermal Deposits and Associated Models .............................................. 216
   6.2.1 Epithermal Deposit Tract Descriptions ......................................................................................... 219
      Permissive Tract ephg01 Karnak-Kanja Hg ..............................................................................................221
      Prospective tract ephg01-p1 Zarmardan .................................................................................................222
      Prospective tract ephg01-p2 Rode-Duzd .................................................................................................224
      Prospective tract ephg01-p3 Durbas .........................................................................................................224
      Prospective tract ephg01-p4 Ghurma .........................................................................................................224
      Prospective tract ephg01-p5 Chashnak-Mushkan ....................................................................................224
      Prospective tract ephg01-p6 Gariba .........................................................................................................227
      Prospective tract ephg01-p7 Kharnak-Kanjar ...........................................................................................227
      Prospective tract ephg01-p8 Darwaza-Surkh-Joi-Gardesh ......................................................................233
      Favorable tract ephg01-f2 Solghoi-Sewak ...............................................................................................234
      Permissive Tract ephg02 North Shaida mercury ......................................................................................238
      Permissive Tract ephg03 Tilak mercury .....................................................................................................240
      Permissive Tract ephg04 Nayak mercury ..................................................................................................242
      Permissive Tract ephg05 Katawaz-mercury .............................................................................................244
6.2 Volcanogenic massive sulfide deposits ..................................................................................................... 252
   6.2.1 Volcanogenic massive sulfide deposit models ............................................................................... 252
   6.2.2 Volcanogenic massive sulfide deposit tract descriptions ................................................................254
      Permissive Tract VMS-01 Late Triassic Balkhab-Gazoghel ................................................................. 256
      Permissive Tract VMS-02 Late Jurassic-Early Cretaceous .................................................................... 261
      Permissive Tract VMS-03 Eocene-Oligocene ......................................................................................... 266
      Permissive Tract VMS-04 Precambrian ................................................................................................. 271
7.0 Deposits associated with sedimentary processes or rocks ........................................................................ 274
7.1 Sediment-hosted copper ............................................................................................................................. 274
   7.1.1 Description of sediment-hosted copper deposit models ...................................................................274
   7.1.2 Description of sediment-hosted copper assessment tracts ............................................................... 276
      Permissive Tract sedcu01 Aynak area .........................................................................................................278
      Favorable tract sedcu01-f1 .......................................................................................................................281
      Propective tracts within tract sedcuf1 .................................................................................................... 281
      Prospective tract sedcu01-p1 Yagh-Darra-Ghuldarra ............................................................................ 281
      Prospective tract sedcu01-p2 ..................................................................................................................281
      Prospective tract sedcu01-p3 Aynak ........................................................................................................283
      Prospective tract sedcu01-p4 Kawkhar-Darband-Kuhundara ............................................................ 283
      Favorable tract sedcu01-f2 Khaidarabad-Sultan Padshah .................................................................... 293
Figures

Figure 1. Map of Afghanistan showing location of known mineral occurrence and 20 prioritized areas.................................................................xxxiv
Figure 2. Map showing location and names of promising mineralized areas resulting for analysis of the preliminary assessment of non-fuel mineral resources in Afghanistan.................................................................xxxv

Figure 1.0-1. Diagram showing how permissive rock covered by less than 1 km is included in permissive tracts. After Singer (1996) .................................................................4
Figure 1.0-2. Flow chart of the 3-part USGS Mineral Assessment Methodology .................................................................7
Figure 1.0-3. Pictures of USGS-AGS Assessment Team, Denver Colorado, January, 2007 .................................................................9
Figure 1.0-4. Pictures of Assessment Team Meeting, Denver, Colorado .................................................................10
Figure 1.0-5. Map of Afghanistan showing major structural blocks, plutonic belts, and faults .................................................................12
Figure 1.0-6. Legend of Mineral symbols used in this report .................................................................20

Figure 2.1-1. Graph showing estimated tonnages of Afghan podiform chromite occurrences plotted on the major podiform chromite tonnage curve (after Singer and others, 1986) .................................................................................................................22
Figure 2.1-2. Locations of known podiform chromite and other mineral occurrences in Logar Valley south of Kabul .................................................................................................................24
Figure 2.1-3. Maps showing locations of tracts, areas of interest, and ultramafic-related deposits in Afghanistan. .................................................................................................................26
Figure 2.1-4. Map view and cross sections of one deposit in Logar Valley, Afghanistan (Volin, 1950) .................................................................28
Figure 2.1-5. Location of a known chromite deposit in the Logar Valley, Afghanistan (Volin, 1950) .................................................................28
Figure 2.1-6. Location of a known chromite deposit in Logar Valley, Afghanistan (Volin, 1950) .................................................................29
Figure 2.1-7. Map of a known chromite deposit in Logar Valley, Afghanistan (Volin, 1950) .................................................................29
Figure 2.1-8. Map of a known chromite deposit in Logar Valley, Afghanistan (Volin, 1950) .................................................................30
Figure 2.1-9. Location of a known chromite deposit in Logar Valley, Afghanistan (Volin, 1950) .................................................................30
Figure 2.1-10. Vertical cross section of a known chromite deposit in Logar Valley, Afghanistan (Volin, 1950) .................................................................31
Figure 2.1-11. Vertical cross sections and three dimensional view of a known chromite deposit in Logar Valley, Afghanistan (Volin, 1950) .................................................................................................................................31
Figure 2.1-12. Three dimensional representation of ore blocks in a known chromite deposit in Logar Valley, Afghanistan (Volin, 1950) .................................................................................................................................32
Figure 2.1-13. Location of the Jurgati chromite occurrence, Parwan Province, Afghanistan .................................................................33
Figure 2.1-14. Cumulative distributions for chromite, platinum-group elements, and rocks for the probabilistic estimates of umf01A, the Eocene Ultramafic Rocks of Logar Valley permissive tract .................................................................................................................................33
Figure 2.1-15. Histograms of estimated contained chromite, palladium, iridium, and mineralized rock for undiscovered podiform deposits for the probabilistic estimate for umf01A, the Eocene Ultramafic Rocks of Logar Valley permissive tract .................................................................34
Figure 2.1-16. Location of the Sperkaw and Shodal chromite occurrences in tract umf01B and areas favorable and prospective for the occurrence of podiform chromite deposits in Paktia Province, Afghanistan .................................................................................................................................35
Figure 2.1-17. Cumulative distributions for chromite, platinum-group elements, and rocks for the probabilistic estimates of tract umf01B, the Eocene Ultramafic Rocks near Khost permissive tract.

Figure 2.1-18. Histograms of estimated contained chromite, palladium, iridium, and mineralized rock for undiscovered podiform deposits for the probabilistic estimate for tract umf01B the Eocene Ultramafic Rocks near Khost permissive tract.

Figure 2.1-19. Location of tract umf01C and favorable areas in Paktia Province, Afghanistan. No estimates of undiscovered ultramafic-related deposits were made.

Figure 2.1-20. Location of tract umf01D in southern Afghanistan.

Figure 2.1-21. Location of umf02, the Proterozoic Ultramafic Rock area of interest for ultramafic-hosted mineral deposits is based upon the occurrence of Proterozoic age mafic and ultramafic rocks.

Figure 2.1-22. Area of interest umf03, the Paleozoic Ultramafic Rocks Area of Interest based on the presence of Paleozoic age ultramafic rocks.

Figure 2.1-23. Area of interest umf04 where Mesozoic age mafic and ultramafic rocks are permissive to host deposits that occur in those types of rocks.

Figure 2.2-1. Known talc-magnesite occurrences in Afghanistan and tracts and areas of interest permissive for their presence.

Figure 2.2-2. Locations of ultramafic-hosted talc-magnesite occurrences and ultramafic mineral resource tracts and areas of interest in southeast Afghanistan.

Figure 2.2-3. Location of talc-magnesite and other ultramafic-hosted occurrences in Logar Valley south of Kabul.

Figure 2.2-4. Output of Monte Carlo simulation for mineralized rock in undiscovered ultramafic talc deposits of Tract A, Afghanistan.

Figure 2.2-5. Output of Monte Carlo simulation for talc in undiscovered ultramafic talc deposits of Tract A, Afghanistan.

Figure 2.2-6. Output of Monte Carlo simulation for mineralized rock in undiscovered ultramafic talc deposits of Tract B, Afghanistan.

Figure 2.2-7. Output of Monte Carlo simulation for talc in undiscovered ultramafic talc deposits of Tract B, Afghanistan.

Figure 2.3-1. Locations of serpentine-hosted asbestos occurrences in Afghanistan with known ultramafic intrusions and ultramafic tracts and areas of interest.

Figure 2.3-2. Mineral resource tracts and areas of interest in Logar Valley and near Khost in eastern Afghanistan.

Figure 2.3-3. Serpentine-hosted asbestos occurrences of tract umf01A, the Eocene Ultramafic Rocks of Logar Valley permissive tract, with prospective and favorable areas.

Figure 2.3-4. Location of serpentine-hosted asbestos occurrences and favorable and prospective areas in tract umf01B, Khost and Paktia Provinces, Afghanistan.

Figure 2.3-5. Serpentine-hosted asbestos occurrences north of Kandahar and north of area of interest umf01D.

Figure 2.3-6. Histograms of estimated contained asbestos and mineralized rock for undiscovered serpentine-hosted asbestos deposits for the probabilistic estimate for the Eocene Ultramafic Rocks of Logar Valley permissive tract.

Figure 2.3-7. Cumulative distributions for asbestos and rocks for the probabilistic estimates of the tract umf01B, Eocene Ultramafic Rocks near Khost permissive tract.
Figure 2.3-8. Cumulative distributions for asbestos and mineralized rocks for the probabilistic estimates of the tract umf01B—Eocene Ultramafic Rocks near Khost permissive tract.................................79
Figure 2.3-9. Histograms of estimated contained asbestos and mineralized rock for undiscovered serpentine-hosted asbestos deposits for the probabilistic estimate for tract umf01B—Eocene Ultramafic Rocks near Khost permissive tract ...............................................................80
Figure 2.3-10. Locations of permissive tracts mir01-mir04 and favorable and prospective areas of interest for undiscovered serpentine-hosted asbestos deposits in Afghanistan..................................................82
Figure 2.3-11. Locations of tract mir01 comprised of Proterozoic age mafic and ultramafic intrusive rocks permissive for undiscovered serpentine-hosted asbestos deposits in Afghanistan. .........84
Figure 2.3-12. Location of tract mir02 delineating Mississippian age mafic and ultramafic intrusive rocks permissive for undiscovered serpentine-hosted asbestos deposits in Afghanistan. ..............86
Figure 2.3-13. Location of tract mir03 of Mesozoic mafic and ultramafic intrusive rocks determined to be permissive for undiscovered serpentine-hosted asbestos deposits in Afghanistan..........................88
Figure 2.3-14. Location of tract mir04 of Eocene age mafic and ultramafic intrusive rocks determined to be permissive, favorable, or prospective for undiscovered serpentine-hosted asbestos deposits in Afghanistan.................................................................90
Figure 2.3-15. Locations of tracts of Eocene age mafic and ultramafic intrusive rocks determined to be favorable, or prospective for undiscovered serpentine-hosted asbestos deposits in Afghanistan. .................................................................91

Figure 3.0-1. Map showing Tract cb01 Helmand Basing and the eight possible areas where carbonatite centers might be present within the tract, based on aeromagnetic data from Sweeney and others (2006). .................................................................99
Figure 3.0-2. Map showing ranking of tracts in the carbonatite area of Khanneshin........................................100
Figure 3.0-3. Maps showing volcanic complex with the three Khanneshin carbonatite (U-Th-REE-apatite) mineral occurrences..............................................................................................................101
Figure 3.0-4. Cumulative distributions of phosphorous, REE, niobium and rocks for the probabilistic estimate of the Khanneshin Carbonatite permissive tract cb01 Helmand Basin, Helmand Province. ..............................................................................................................................................102
Figure 3.0-5. Histograms of estimated contained metal and mineralized rock for undiscovered carbonatite deposits containing phosphorous, REE, niobium and rocks for the probabilistic estimate of the Khanneshin Carbonatite permissive tract cb01 Helmand Basin. .............................................103

Figure 4.1-1. Map showing location of areas in Afghanistan that may contain deposits of tin and (or) tungsten. Permissive tract snw01 (Anar Dara) is delineated specifically for vein, stockwork, and porphyry deposits. ...........................................................................................................109
Figure 4.1-2. Map showing Anar Dara (snw01) permissive tract in west Afghanistan, showing mineral prospects and occurrences, geochemical halos, and outcrops of granitic rock ......................110
Figure 4.1-3. LANDSAT image (bands 1, 2, and 3) showing granite stock associated with Sn-bearing mineral prospects in the Tourmaline area, Afghanistan.................................................................112
Figure 4.1-4. LANDSAT image (bands 7, 3, and 1), showing granitic pluton and the location of the Baytamur, Band, Maydan-Ahu, and Adamkhei prospects, Arghandab area of interest, Afghanistan. ..............................................................................................................................................114
Figure 4.2-1. Location of permissive tract fluor01 Bakhud for undiscovered fluorite deposits, showing location of geochemical halo anomalies .................................................................121
Figure 4.2-2. Map showing features of fluorite occurrences in south central Afghanistan.............................122
Figure 4.3-1. Area permissive for pegmatites affiliated with Oligocene plutons in Afghanistan.....................125

Figure 5.1-1. Map of Afghanistan, showing the location and identification of assessment tracts for porphyry copper deposits. ...........................................................................................................................134
Figure 5.1-2. Map showing the Chagai east permissive tract (ppycu01) for undiscovered porphyry copper deposits and skarn copper deposits..................................................................................................................136
Figure 5.1-3. Cumulative distribution of estimated contained metal and mineralized rock in the Chagai east permissive tract (ppycu01). ...........................................................................................................................138
Figure 5.1-4. Histograms of estimated contained metal and mineralized rock in the Chagai east permissive tract (ppycu01). ...........................................................................................................................139
Figure 5.1-5. Map showing the Chagai west permissive tract (ppycu02) for undiscovered porphyry copper and skarn copper deposits. ..................................................................................................................141
Figure 5.1-6. Cumulative distribution of estimated contained metal and mineralized rock in the Chagai west permissive tract (ppycu02). ...........................................................................................................................143
Figure 5.1-7. Histograms of estimated contained metal and mineralized rock in the Chagai west permissive tract (ppycu02). ...........................................................................................................................144
Figure 5.1-8. Map showing the Spin Boldak permissive tract (ppycu03) for undiscovered porphyry copper deposits and skarn copper deposits. ..................................................................................................................146
Figure 5.1-9. Cumulative distribution of estimated contained metal and mineralized rock in the Spin Boldak permissive tract (ppycu03). ...........................................................................................................................148
Figure 5.1-10. Histograms of estimated contained metal and mineralized rock in the Spin Boldak permissive tract (ppycu03). ...........................................................................................................................149
Figure 5.1-11. Map showing the Saindak north permissive tract (ppycu04) for undiscovered porphyry copper and skarn copper deposits. ..................................................................................................................151
Figure 5.1-12. Cumulative distribution of estimated contained metal and mineralized rock in the Saindak north permissive tract (ppycu02). ...........................................................................................................................153
Figure 5.1-13. Histograms of estimated contained metal and mineralized rock in the Saindak north permissive tract (ppycu02). ...........................................................................................................................154
Figure 5.1-14. Map showing the Kundalyan-Zarkashan permissive tract (ppycu05) for undiscovered porphyry copper and skarn copper deposits. ..................................................................................................................156
Figure 5.1-15. Map of the Zarkashan part of the Kundalyan-Zarkashan porphyry copper tract. .......................157
Figure 5.1-16. Map of the Kundalyan part of the Kundalyan-Zarkashan porphyry copper permissive tract. ...........................................................................................................................159
Figure 5.1-17. Aerial view of Kundalyan area. Barren subdued slopes are map unit KP, gbm. .............................159
Figure 5.1-18. Evidence of mineral exploration in the Kundalyan area..................................................................160
Figure 5.1-19. Cumulative distribution of estimated contained metal and mineralized rock in the Kundalyan-Zarkashan permissive tract (ppycu05). ..................................................................................................................161
Figure 5.1-20. Histograms of estimated contained metal and mineralized rock in the Kundalyan-Zarkashan permissive tract (ppycu05). ..................................................................................................................162
Figure 5.1-21. Map showing the Argandhab permissive tract (ppycu06) for undiscovered porphyry copper deposits and skarn copper deposits. ..................................................................................................................164
Figure 5.1-22. Cumulative distribution of estimated contained metal and mineralized rock in the Argandhab permissive tract (ppycu06). ..................................................................................................................166
Figure 5.1-23. Histograms of estimated contained metal and mineralized rock in the Argandhab permissive tract (ppycu06). .........................................................................................................................167

Figure 5.1-24. Map showing the Katawaz permissive tract (ppycu07) for undiscovered porphyry copper and skarn copper deposits. ..........................................................................................................................168

Figure 5.1-25. Cumulative distribution of estimated contained metal and mineralized rock in the Katawaz permissive tract (ppycu07). ........................................................................................................................................170

Figure 5.1-26. Histograms of estimated contained metal and mineralized rock in the Katawaz permissive tract (ppycu07). ........................................................................................................................................171

Figure 5.1-27. Map showing the Feroz Koh permissive tract (ppycu08) for undiscovered porphyry copper deposits and skarn copper deposits. ........................................................................................................174

Figure 5.1-28. Cumulative distribution of estimated contained metal and mineralized rock in the Feroz Koh permissive tract (ppycu08). .............................................................................................................175

Figure 5.1-29. Histograms of estimated contained metal and mineralized rock in the Feroz Koh permissive tract (ppycu08). ........................................................................................................................................176

Figure 5.1-30. Map showing the Farah Rod permissive tract (ppycu09) for undiscovered porphyry copper deposits and skarn copper deposits. ........................................................................................................179

Figure 5.1-31. Cumulative distribution of estimated contained metal and mineralized rock in the Farah Rod permissive tract (ppycu09). .................................................................................................................180

Figure 5.1-32. Histograms of estimated contained metal and mineralized rock in the Farah Rod permissive tract (ppycu09). .........................................................................................................................181

Figure 5.1-33. Map showing the West Hindu Kush permissive tract (ppycu10) for undiscovered porphyry copper deposits and skarn copper deposits. ......................................................................................184

Figure 5.1-34. Cumulative distribution of estimated contained metal and mineralized rock in the West Hindu Kush permissive tract (ppycu10). ..............................................................................................185

Figure 5.1-35. Histograms of estimated contained metal and mineralized rock in the West Hindu Kush permissive tract (ppycu10). .................................................................................................................186

Figure 5.1-36. Map showing the West Badakhshan permissive tract (ppycu11) for undiscovered porphyry copper deposits. ..........................................................................................................................187

Figure 5.1-37. Map showing the Helmand permissive tract (ppycu12) for undiscovered porphyry copper and skarn copper deposits. ..................................................................................................................189

Figure 5.1-38. Cumulative distribution of estimated contained metal and mineralized rock in the Helmand permissive tract (ppycu12). .................................................................................................................190

Figure 5.1-39. Histograms of estimated contained metal and mineralized rock in the Helmand permissive tract (ppycu12). .........................................................................................................................191

Figure 5.2-1. Map showing location of tracts for lode gold deposits in Afghanistan. Section 5.2 discusses the pluton-related gold veins and skarns in Kandahar, Zabul and Ghazni Provinces...194

Figure 5.2-2. Map showing location of permissive tract gold03 and two internal favorable tracts gold03-f1 and gold03-f2 for undiscovered pluton-related gold deposits. ......................................................196

Figure 5.2-3. Map showing location of favorable tract gold03-f1 in Kandahar and Zabul provinces with internal prospective tracts gold03-p1 and gold03-p2. .................................................................198

Figure 5.2-4. Maps showing parts of tract permissive gold03-f1 where aeromagnetic data were available for use in the assessment. ...........................................................................................................199

Figure 5.2-5. Map showing location of prospective tracts gold03-p1 and gold03-p2 in Zabul Province. .200

Figure 5.2-6. Map showing location of tract gold03-f2 tract favorable for undiscovered pluton-related gold deposits and location of internal prospective tracts gold03-p3 and gold03-p4. ..............202
Figure 5.2-7. Maps showing location of Prospective tracts gold03-p3 and gold01-p4 in Ghazni Province.

Figure 6.1-1. Permissive, favorable and prospective tracts for undiscovered epithermal mercury deposits in Afghanistan.

Figure 6.1-2. Location of permissive tract for epithermal (mercury) deposits, ephg01 Taywara mercury, showing province boundaries and shaded relief and internal favorable and prospective tracts.

Figure 6.1-3. Location of prospective tract ephg01-p1 in northern Farah province, showing location of the Zarmardan mercury occurrence.

Figure 6.1-4. Location of prospective tracts ephg01-p2, p3, and p4 containing vein and contact-related base-metal occurrences associated with Eocene to Oligocene plutons and stocks.

Figure 6.1-5. Prospective tract ephg01-p5 in northeastern Farah province, showing location of the three known mercury-bearing mineral occurrences there.

Figure 6.1-6. Prospective tracts ephg01-p6 and ephg01-p7 within favorable tract ephg01-f1 and permissive tract ephg01, for undiscovered mercury deposits in southwest Ghor Province.

Figure 6.1-7. Clusters of mercury occurrences, many with ancient workings, in the southwest lobe of prospective tract ephg01-p7 south of Taywara in southwest Ghor Province. This is the most highly mineralized area known in Afghanistan for mercury.

Figure 6.1-8. Prospects and shape of northeast part of the prospective tract ephg01-p7 for mercury deposits in Uruzgan Province.

Figure 6.1-9. Map showing location of prospective tract ephg01-p8 containing the Darwaza mercury occurrence and two other occurrences. The tract lies at the northeastern tip of the favorable tract ephg01-f1.

Figure 6.1-10. Map showing location of favorable mercury epithermal tract ephg01-f2 in Bamyan Province within permissive tract ephg01. The three mineral occurrences also lie proximal to elongate Cretaceous dunite bodies.

Figure 6.1-11. Histogram of estimated contained metal and mineralized rock in tract ephg01.

Figure 6.1-12. Cumulative distributions of estimated contained metal and mineralized rock in the Karnak-Kanja Hg tract ephg01.

Figure 6.1-13. Location of permissive tract ephg02 for undiscovered mercury epithermal deposits and related precious-metal epithermal deposits in Herat Province.

Figure 6.1-14. Location of the permissive tract ephg03 Tilak for hot-spring mercury deposits in Ghowr Province and location of known mercury mineral occurrences and geochemical anomalous halos.

Figure 6.1-15. Permissive tract ephg04 Nayak for undiscovered epithermal mercury and precious-metal deposits in Herat Province.

Figure 6.1-16. Permissive tract ephg05 Katawaz for undiscovered epithermal mercury deposits and precious-metal epithermal deposits in southeast Afghanistan.

Figure 6.1-17. Map of Spira-Zanda Gharay area in eastern Paktika and western Khost Provinces on the faulted eastern margin of permissive tract ephg03 Katawaz mercury.

Figure 6.1-18. Area in west part of permissive tract ephg05 for undiscovered epithermal mercury deposits showing Miocene intrusive rocks (reddish color), and ASTER alteration patches from Mars and Rowan (2006).

Figure 6.1-19. ASTER anomaly along northeast-striking linear zone coinciding with a mercury anomaly in part of tract ephg05 in the Katawaz Basin near Sharah Woluswal.
Figure 6.2-1. Map showing total permissive tracts for volcanogenic massive sulfide deposits in Afghanistan. ..............................................................255

Figure 6.2-2. Map showing location of the four (4) parts of permissive tract VMS-01 Late Triassic Balkhab-Gazoghel (yellow) for undiscovered volcanogenic massive sulfide deposits. ..........................257

Figure 6.2-3. Landsat imagery showing the location of the Balkhab volcanogenic massive sulfide occurrence in Sari Pul Province (VMS01a). ..........................................................................................258

Figure 6.2-4. Map showing geology and location of western part of permissive tract VMS-01-Triassic Balkhab-Gazoghel for undiscovered volcanogenic massive sulfide deposits and the location of the Balkhab mineral occurrence. ..................................................259

Figure 6.2-5. Map showing location of two volcanogenic massive sulfide occurrences Gazoghel and Gazoghel I in central Baghlan Province in the eastern part of a central part of permissive tract VMS-01 Late Triassic Balkhab-Gazghel (VMS-01b) for undiscovered volcanogenic massive sulfide deposits. .................................................................260

Figure 6.2-6. Map showing location and three parts of permissive tract VMS-02 Late Jurassic-Early Cretaceous for undiscovered volcanogenic massive sulfide deposits. .........................................................................................262

Figure 6.2-7. Maps showing the western most part of the permissive tract VMS-02 Late Jurassic-Early Cretaceous for undiscovered volcanogenic massive sulfide deposits in Herat Province. .............263

Figure 6.2-8. Map showing the central part of permissive tract VMS-02 Upper Jurassic-Lower Cretaceous containing the Shaida VMS occurrence and also showing the eastern parts of the tract. ..................................................................................................................265

Figure 6.2-9. Map showing location of parts of permissive tract VMS-03 Eocene-Oligocene for undiscovered volcanogenic massive sulfide deposits. .........................................................................................268

Figure 6.2-10. LANDSAT image of the Durbas area in Farah Province within permissive tract VMS-03. .................................................................269

Figure 6.2-11. Distribution of the part of tract VMS-03 Eocene-Oligocene in Farah Province in the Durbas area. .................................................................................................................................270

Figure 6.2-12. Map showing distribution of permissive tract VMS-04 Precambrian for undiscovered volcanogenic massive sulfide deposits in Afghanistan. ........................................................................272

Figure 7.1-1. Map showing location of tracts sedcu01 and sedcu02 where undiscovered sediment-hosted copper deposits might be present. ......................................................................................................277

Figure 7.1-2. Map showing version one of permissive tract sedcu01 and locations of known deposits and prospects (orange squares) from Ludington and others (2007). ..................................................279

Figure 7.1-3. Maps showing modified location of permissive tract sedcu01 after subtraction of Logar Eocene intrusive dunite body in the south-central parts and extension of a western limb, south of the city of Kabul. .............................................................................................................280

Figure 7.1-4. Map showing location of central parts of permissive tract sedcu01 Aynak including two internal favorable tracts sedcu01-f1 and sedcu01-f2. ........................................................................................286

Figure 7.1-5. Maps showing location of favorable tract sedcu01-f1 and prospective tracts sedcu01-p1, p2, p3 and p4, Kabul and Logar Provinces. ........................................................................................................287

Figure 7.1-6. Map showing location of stratabound copper occurrences in southern Kabul and northern Logar Provinces. .................................................................................................................288

Figure 7.1-7. Geologic maps and sections of the (a) Darband and (b) Aynak sediment-hosted copper deposits in the Kabul district (Afghanistan Geological Survey, 2006a and b). ..................................289

Figure 7.1-8. Cumulative distribution of estimated contained metal and mineralized rock in permissive tract sedcu01 Aynak for undiscovered sediment-hosted deposits, assuming the Aynak-type
deposits have the same grade-tonnage distribution as sediment-hosted reduced-facies copper deposits.  

Figure 7.1-9. Histograms of estimated contained metal and mineralized rock in permissive tract sedcu01 Aynak for undiscovered sediment-hosted deposits, assuming that the Aynak-type deposits have the same grade-tonnage distribution as that for sediment-hosted reduced-facies copper deposits.  

Figure 7.1-10. Map showing location of favorable tract sedcu01-f2 Khairdarabad-Sultan Padshah within permissive tract sedcu01 Aynak area for undiscovered sediment-hosted copper deposits in Kabul Province.  

Figure 7.1-11. Map showing location of multiple parts of permissive tract sedcu02 for undiscovered sediment-hosted copper deposits in Afghanistan.  

Figure 7.2-1. Map showing location of permissive and favorable tracts for sediment-hosted lead-zinc deposits in Afghanistan.  

Figure 7.2-2. Maps showing location of total permissive tracts for sediment-hosted lead-zinc deposits in Afghanistan.  

Figure 7.2-3. Map showing location of permissive tract pbzn01 Phanerozoic sediment-hosted lead-zinc.  

Figure 7.2-4. Central parts of permissive tract pbzn01 Phanerozoic sediment-hosted lead-zinc in Ghor Province, showing the location of favorable tracts pbzn01-f1 Nalbandon, -f2 Gharghanawl-Gawmazar, and -f3 East Ghor.  

Figure 7.2-5. Map showing location of favorable tract pbzn01-f1 in three parts, one of which contains the Nalbandon deposit.  

Figure 7.2-6. Favorable tract pbzn01-f2 Gharghanawl-Gawmazar in Ghor Province containing the Gharghanaw, Hasan Sansalaghay, Shekhlawas, and Gawmazar lead-zinc occurrences.  

Figure 7.2-7. Favorable tract pbzn01-f3 in east-central Ghor Province.  

Figure 7.2-8. Four areas within eastern Afghanistan that contain permissive stratigraphy for the occurrence of stratabound sediment-hosted lead-zinc deposits in rocks of Paleozoic and Early Mesozoic age.  

Figure 7.2-9. Map showing location of areas of interest 1 and 2 for undiscovered lead and zinc deposits.  

Figure 7.2-10. Map showing location of areas of interest 3 and 4 for undiscovered lead and zinc deposits.  

Figure 7.2-11. Map showing location of area 5 within permissive tract pbzn01 (yellow) in relation to geochemical halo anomaly for lead in Herat Province.  

Figure 7.2-12. (a) Map showing location of permissive tract pbzn02 for sediment-hosted lead-zinc deposits within Lower Cretaceous sedimentary rocks (b) Location of the Talah lead-zinc occurrence within permissive tract pbzn02 in Uruzgan Province in the eastern parts of the tract.  

Figure 7.2-13. Permissive tract pbzn03--Proterozoic (and al Precambrian) rocks in Afghanistan that may have potential for sediment hosted lead-zinc deposits.  

Figure 7.2-14. Map of parts of permissive tract pbzn03 for sediment-hosted lead-zinc deposits in Proterozoic rocks in Parwan Province.  

Figure 7.3-1. Maps showing location of some map units that host clay deposits in Afghanistan.  

Figure 7.3-2. Maps showing distribution of brick-clay occurrences in Herat Province within Cenozoic sedimentary rocks, map unit Q2a.
Figure 10.3-13. Outline of Basin 4 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits..............................................................519
Figure 10.3-13c. Outline of Basin 4 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees where only areas in green are permissive for sand and gravel deposits in alluvial fans....................................................................................................................520
Figure 10.3-14. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in Basin 4............................................................................................................................................................522
Figure 10.3-15. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 4 tracts..................................................................................................................................523
Figure 10.3-16. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Basin 4............................................................................................................................................................525
Figure 10.3-17. Outline of Basin 5 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits.....................................................527
Figure 10.3-17c. Outline of Basin 5 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees where only areas in green are permissive for sand and gravel deposits in alluvial fans....................................................................................................................528
Figure 10.3-18. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 5 tracts................................................................................................................................................................530
Figure 10.3-19. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 5 tracts............................................................................................................................................................531
Figure 10.3-20. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Basin 5............................................................................................................................................................533
Figure 10.3-21. Outline of Basin 6 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits............................................................................................................................................................535
Figure 10.3-21c. Outline of Basin 6 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees where only areas in green are permissive for sand and gravel deposits in alluvial fans............................................................................................................................................................536
Figure 10.3-22. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in Basin 6................................................................................................................................................................538
Figure 10.3-23. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 6 tracts............................................................................................................................................................539
Figure 10.3-24. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Basin 6............................................................................................................................................................541
Figure 10.3-25. Outline of Basin 7 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits............................................................................................................................................................543
Figure 10.3-25c. Outline of Basin 7 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees where only areas in green are permissive for sand and gravel deposits in alluvial fans............................................................................................................................................................544
Figure 10.3-26. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 7 tracts................................................................................................................................................................546
Figure 10.3-27. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in Basin 7 buffer zones............................................................................................................................................................547
Figure 10.3-28. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Basin 7............................................................................................................................................................549
Figure 10.3-45. Outline of Basin 12 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits.................................................................583
Figure 10.3-49c. Outline of Basin 12 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees where only areas in green are permissive for sand and gravel deposits in alluvial fans...........................................................................................................584
Figure 10.3-46. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 12 tracts..................................................................................................................................................586
Figure 10.3-47. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 12 tracts.........................................................................................................................587
Figure 10.3-48. Distribution of sand and gravel resources in sand and gravel deposits in Basin 12 alluvial fans..................................................................................................................................................587
Figure 10.3-49. Outline of Basin 13 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits.................................................................591
Figure 10.3-49c. Outline of Basin 13 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees where only areas in green are permissive for sand and gravel deposits in alluvial fans...........................................................................................................592
Figure 10.3-50. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 13 tracts..................................................................................................................................................594
Figure 10.3-51. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 13 buffer zones...........................................................................................................................................595
Figure 10.3-52. Distribution of sand and gravel resources in sand and gravel deposits in Basin 13 alluvial fans..................................................................................................................................................597
Figure 10.3-53. Outline of Basin 14 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits.................................................................598
Figure 10.3-53c. Outline of Basin 14 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees where only areas in green are permissive for sand and gravel deposits in alluvial fans...........................................................................................................599
Figure 10.3-54. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 14 tracts..................................................................................................................................................601
Figure 10.3-55. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in Basin 14 buffer zones...........................................................................................................................................603
Figure 10.3-56. Distribution of sand and gravel resources in sand and gravel deposits in Basin 14 alluvial fans..................................................................................................................................................605
Figure 10.3-57. Outline of Basin 15 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits.................................................................607
Figure 10.3-57c. Outline of Basin 15 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees where only areas in green are permissive for sand and gravel deposits in alluvial fans...........................................................................................................608
Figure 10.3-58. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 15 tracts..................................................................................................................................................610
Figure 10.3-59. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 15 tracts...........................................................................................................................................611
Figure 10.3-60. Distribution of sand and gravel resources in sand and gravel deposits in Basin 15 alluvial fans..................................................................................................................................................613
Figure 10.3-61. Outline of Basin 16 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits.................................................................615

Figure 10.3-61c. Outline of Basin 16 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees where only areas in green are permissive for sand and gravel deposits in alluvial fans.................................................................616

Figure 10.3-62. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 16 tracts.........................................................................................................................................................618

Figure 10.3-63. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 16 tracts........................................................................................................................................619

Figure 10.3-64. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Basin 16.........................................................................................................................................................621

Figure 10.3-65. Outline of Basin 17 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits.................................................................623

Figure 10.3-65c. Outline of Basin 17 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees where only areas in green are permissive for sand and gravel deposits in alluvial fans.................................................................624

Figure 10.3-66. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 17 tracts.........................................................................................................................................................626

Figure 10.3-67. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 17 buffer zones.........................................................................................................................................................627

Figure 10.3-68. Distribution of sand and gravel resources in sand and gravel deposits in Basin 17 alluvial fans.........................................................................................................................................................629

Figure 10.3-69. Outline of Basin 18 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits.................................................................631

Figure 10.3-69c. Outline of Basin 18 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees where only areas in green are permissive for sand and gravel deposits in alluvial fans.................................................................632

Figure 10.3-70. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 18 tracts.........................................................................................................................................................634

Figure 10.3-71. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in buffer zones in Basin 18.........................................................................................................................................................635

Figure 10.3-72. Distribution of sand and gravel resources in sand and gravel deposits in Basin 18 alluvial fans.........................................................................................................................................................637

Figure 10.3-73. Outline of Area A showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits.................................................................639

Figure 10.3-73c. Outline of Area A showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees where only areas in green are permissive for sand and gravel deposits in alluvial fans.................................................................640

Figure 10.3-74. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in Area A.........................................................................................................................................................642

Figure 10.3-75. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in Area A buffer zones.........................................................................................................................................................643

Figure 10.3-76. Outline of Area B showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits.................................................................645
Figure 11.2-1. Areas permissive and favorable for the occurrence of limestone deposits in Afghanistan.

Figure 11.4-2. Areas permissive and favorable for the occurrence of limestone deposits in Afghanistan.

Figure 11.3-1. Afghanistan cities with known marble processing factories and the numbers of those factories in the cities (after USAID and others, 2006).

Figure 11.3-2. Tracts permissive and favorable for the occurrence of undiscovered marble dimension stone deposits in Afghanistan.

Figure 11.4-1. Tracts permissive and favorable for the occurrence of undiscovered travertine dimension stone deposits in Afghanistan.

Figure 11.4-2 An area of interest within tract dms04 is in Helmand Province along the Pakistan border. In this area, travertine is mined and carved into small figurines and made into other objects.

Figure 11.4-3. Part of tract dms04 in Kandahar Province along the border with Pakistan where there is a known travertine deposit and travertine has been produced.

Figure 11.5-1. Tracts permissive and favorable for the occurrence of undiscovered sandstone dimension stone deposits in Afghanistan.

Figure 12.1-1. Location of area of interest for undiscovered emerald deposits in the Panjsher Valley area, showing location of known emerald deposits and main geologic units from Doebrich and Wahl, (2006).

Figure 12.2-1. Map showing location of the Jegdalek ruby occurrence in Qarghayai District southwest Laghman Province.

Figure 12.2-2. Location of the Ab-i-Panja (Balal) gem area in northern Badakhshan Province, Ishkashim District.

Figure 12.3-1. Map showing location of the Sary-Sang Lapis Lazuli Mine and associated prospects in the Kokoschka River Valley.

Figure 12.3-2. Example of Lapis lazuli specimens and other minerals from the Sary-Sang Lapis Lazuli Mine and associated prospects in the Kokoschka River Valley.

Figure 12.4-1. Maps showing location of pegmatite fields in Afghanistan modified from those described by Abdullah and others (1977).

Figure 12.4-2. Map showing location of tourmaline occurrences (pink diamonds) in pegmatite fields (yellow) in northeastern Afghanistan.

Figure 12.4-3. Map showing location of Nilaw-Kolum and Kulam tourmaline-kunzite occurrences in Nuristan Province, Mandol district, containing large areas of kunzite with associated amounts of tourmaline, beryllium, cesium, tantalum, rubidium and quartz.
Tables

Table 1. Summary of known resources and estimated undiscovered resources for selected commodities in Afghanistan identified by the U.S. Com (1977) ered (metric tonnes) MEA Aluminum 4,535,000 metric tons at 50.5 Geological Survey-Afghanistan Geological Survey Joint Mineral Resource Assessment Team. .................................................................xxxiii

Table 1.0-1. Classification of mineral deposit models by deposit environment ....................................................13
Table 1.0-2. Metallogenic character of Afghanistan plutonic belts depicted on figure 1.0-3. .............................14

Table 2.1-1. Probability estimates of undiscovered podiform chromite deposits in tract umf01A. ...................27
Table 2.1-2 Table showing probabilistic distribution of estimated contained metal and mineralized rock for undiscovered podiform chromite deposits for the probabilistic estimates of the Eocene........36
Table 2.1-3. Consensus probability estimates of undiscovered podiform chromite deposits in tract umf01B. ........................................................................................................................................38
Table 2.1-4 Table showing probabilistic distribution of estimated contained metal and mineralized rock for undiscovered podiform chromite deposits for the probabilistic estimates of tract umf01B the Eocene Ultramafic Rocks near Khost permissive tract .........................................................42
Table 2.2-1. Ultramafic talc and magnesite occurrences in Afghanistan and talc-magnesite of uncertain affiliation (indicated by “*”) ........................................................................................................55
Table 2.2-2. Probability estimate of undiscovered ultramafic-hosted talc-magnesite deposits in tract umf01A. ........................................................................................................................................58
Table 2.3-1. Probability estimates of undiscovered serpentine-hosted asbestos deposits in tract umf01A. ........................................................................................................................................74
Table 2.3-2. Table showing probabilistic distribution of estimated contained asbestos and mineralized rock for undiscovered serpentine-hosted asbestos deposits for the probabilistic estimates of tract umf01A—Eocene Ultramafic Rocks of Logar Valley permissive tract. ........................................................................77
Table 2.3-3. Probability estimates of undiscovered serpentine-hosted asbestos deposits in tract umf01A. ........................................................................................................................................78
Table 2.3-4. Table showing probabilistic distribution of estimated contained asbestos and mineralized rock for undiscovered serpentine-hosted asbestos deposits for the probabilistic estimates of tract umf01B—Eocene Ultramafic Rocks Near Khost permissive tract. ........................................................................81

Table 3.0-1. Assessment team estimates of undiscovered carbonatite deposits in the cb01 Helmund Basin permissive tract ........................................................................................................................................98
Table 3.0-2. Mean estimates of metric tons of undiscovered phosphate, REE, niobium, and rock in undiscovered carbonatite tract. ........................................................................................................98
Table 3.0-3. Table showing probabilistic distribution of estimated contained metal and mineralized rock for undiscovered carbonatite deposits containing phosphorous, REE, niobium, and rocks for the probabilistic estimate of the Khanneshin Carbonatite permissive tract cb01 Helmand Basin........................................................................................................................................104

Table 4.1-1. Median tonnage and grade for tin and tungsten occurrence models .............................................106
Table 4.3-1. Pegmatite fields in Afghanistan. ...........................................................................................................125

Table 5.1-1. Median tonnage and grade for porphyry copper and associated deposit models. ......................130
Table 5.1-2. Table summarizing statistical parameters for the assessment of the Chagai east permissive tract (ppycu01). The mean number of expected deposits is 1.3. .................................................................137
Table 5.1-3. Table summarizing statistical parameters for the assessment of the Chagai west permissive tract (ppycu02). The mean number of expected deposits is 1.0. .................................................................142
Table 5.1-4. Table summarizing statistical parameters for the assessment of the Spin Boldak permissive tract (ppycu03). The mean number of expected deposits is 0.6. .................................................................147
Table 5.1-5. Table summarizing statistical parameters for the assessment of the Saindak north permissive tract (ppycu04). The mean expected number of deposits is 0.9. .................................................................152
Table 5.1-6. Table summarizing statistical parameters for the assessment of the Kundalyan-Zarkashan permissive tract (ppycu05). The mean expected number of deposits is 1.0......................................................161
Table 5.1-7. Table summarizing statistical parameters for the assessment of the Argandhab permissive tract (ppycu06). The mean expected number of deposits is 0.6. .................................................................165
Table 5.1-8. Table summarizing statistical parameters for the assessment of the Katawaz permissive tract (ppycu07). The mean expected number of deposits is 0.6. .................................................................169
Table 5.1-9. Table summarizing statistical parameters for the assessment of the Feroz Koh permissive tract (ppycu08). The mean expected number of deposits is 0.6. .................................................................173
Table 5.1-10. Table summarizing statistical parameters for the assessment of the Farah Rod permissive tract (ppycu09). The mean expected number of deposits is 1.3. .................................................................178
Table 5.1-11. Table summarizing statistical parameters for the assessment of the West Hindu Kush permissive tract (ppycu10). The mean expected number of deposits is 0.3......................................................183
Table 5.1-12. Table summarizing statistical parameters for the assessment of the Helmand permissive tract (ppycu12). The mean expected number of deposits is 0.3. .................................................................189
Table 5.1-13. Summary of Estimates of undiscovered porphyry copper deposits in Afghanistan. .................193

Table 6.1-1. Mercury-rich mineral occurrences of Afghanistan. ..........................................................................210
Table 6.1-2. Table showing probabilistic distribution of estimated contained metal and mineralized rock for undiscovered hot-spring mercury deposits permissive tract ephg01 Karnak-Kanja Hg. ..........237

Table 7.1-1. Table of output for permissive tract sedcu01 Aynak for undiscovered sediment-hosted deposits, assuming that the Aynak-type deposits have the same grade-tonnage distribution as that for sediment-hosted reduced-facies copper deposits.................................................................292

Table 8.3A-1. Probability estimates for undiscovered potash-bearing bedded halite deposits in tract AFK-01. .........................................................................................................................................................372
Table 8.3A-2. Table showing probabilistic distribution of estimated contained asbestos and mineralized rock for undiscovered potash-bearing bedded halite deposits for the probabilistic estimated for Jurassic evaporites of the Afghan-Tajik basin. .................................................................................................................................................................376

Table 9.2-1. Probability estimates of undiscovered disseminated flake graphite deposits in tract dvg01. ....438
Table 9.2-2. Table showing probabilistic distribution of contained metal and mineralized rock for undiscovered disseminated flake graphite deposits for the probabilistic estimates of the Badakhshan Archean permissive tract.................................................................443
Table 9.3-1. Some metasomatic talc-magnesite occurrences in Afghanistan. .................................................................457

Table 10.2-1. Gold placer deposits and estimated known resources of Afghanistan (Abdullah and others, 1977). ..................................................................................................................................................473

Table 10.3-1. Summary of the amount of sand and gravel (in million cubic meters) expected in both discovered and undiscovered deposits for fluvial sand and gravel deposit type and alluvial fan sand and gravel type for 24 river basins and other areas in Afghanistan. ........................................492

Table 10.3-2. Estimated number of fluvial sand and gravel deposits in Basin 1, both discovered and undiscovered, calculated using the MDD model. ..........................................................................................498

Table 10.3-3. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.................................................................499

Table 10.3-4. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 1. ......................................................................................................................501

Table 10.3-5. Estimated number of fluvial sand and gravel deposits in Basin 2, both discovered and undiscovered, calculated using the MDD model. ..........................................................................................506

Table 10.3-6. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.................................................................507

Table 10.3-7. Estimate number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 2........................................................................................................................................509

Table 10.3-8. Estimated number of fluvial sand and gravel deposits in Basin 3 assessment zone, both discovered and undiscovered, calculated using the MDD model. .....................................................514

Table 10.3-9. Estimate number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 3........................................................................................................................................516

Table 10.3-10. Estimated number of fluvial sand and gravel deposits in Basin 4, both discovered and undiscovered, calculated using the MDD model. .......................................................................................521

Table 10.3-11. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.................................................................520

Table 10.3-12. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 4. ......................................................................................................................524

Table 10.3-13. Estimated number of fluvial sand and gravel deposits in Basin 5, both discovered and undiscovered, calculated using the MDD model. .......................................................................................529

Table 10.3-14. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.................................................................530

Table 10.3-15. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 5........................................................................................................................................532

Table 10.3-16. Estimated number of fluvial sand and gravel deposits in Basin 6, both discovered and undiscovered, calculated using the MDD model. .......................................................................................537

Table 10.3-17. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.................................................................538

Table 10.3-18. Estimated number of sand and gravel deposits both discovered and undiscovered, in alluvial fans in Basin 6. ......................................................................................................................540

Table 10.3-19. Estimated number of fluvial sand and gravel deposits in Basin 7, both discovered and undiscovered, calculated using the MDD model. .......................................................................................545

Table 10.3-20. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.................................................................546
Table 10.3-21. Estimated number of fluvial sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 7.................................................................548
Table 10.3-22. Estimated number of fluvial sand and gravel deposits in Basin 8, both discovered and undiscovered, calculated using the MDD model......................................................553
Table 10.3-23. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model..................................................554
Table 10.3-24. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 8 ...........................................................................................................556
Table 10.3-25. Estimated number of fluvial sand and gravel deposits in Basin 9, both discovered and undiscovered, calculated using the MDD model......................................................561
Table 10.3-26. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model..................................................562
Table 10.3-27. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 9 ...........................................................................................................564
Table 10.3-28. Estimated number of fluvial sand and gravel deposits in Basin 10, both discovered and undiscovered, calculated using the MDD model......................................................569
Table 10.3-29. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model..................................................570
Table 10.3-30. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 10 ...........................................................................................................572
Table 10.3-31. Estimated number of fluvial sand and gravel deposits in Basin 11, both discovered and undiscovered, calculated using the MDD model......................................................577
Table 10.3-32. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model..................................................578
Table 10.3-33. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 11 ...........................................................................................................580
Table 10.3-34. Estimated number of fluvial sand and gravel deposits in Basin 12, both discovered and undiscovered, calculated using the MDD model......................................................585
Table 10.3-35. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model..................................................586
Table 10.3-36. Estimated number of sand and gravel deposits, both discovered and undiscovered, in alluvial fans in Basin 12 ...........................................................................................................588
Table 10.3-37. Estimated number of fluvial sand and gravel deposits in Basin 13, both discovered and undiscovered, calculated using the MDD model......................................................593
Table 10.3-38. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model..................................................594
Table 10.3-39. Estimated number of sand and gravel deposits, both discovered and undiscovered, in alluvial fans in Basin 13 ...........................................................................................................596
Table 10.3-40. Estimated number of fluvial sand and gravel deposits in Basin 14, both discovered and undiscovered, calculated using the MDD model......................................................601
Table 10.3-41. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model..................................................602
Table 10.3-42. Estimated number of sand and gravel deposits, both discovered and undiscovered, in alluvial fans in Basin 14 ...........................................................................................................604
Table 10.3-43. Estimated number of fluvial sand and gravel deposits in Basin 15, both discovered and undiscovered, calculated using the MDD model. .................................................................609
Table 10.3-44. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model. .........................................................610
Table 10.3-45. Estimated number of sand and gravel deposits, both discovered and undiscovered, in alluvial fans in Basin 15.....................................................................................................612
Table 10.3-46. Estimated number of fluvial sand and gravel deposits in Basin 16, both discovered and undiscovered, calculated using the MDD model. .................................................................617
Table 10.3-47. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model. .........................................................618
Table 10.3-48. Estimate number of fluvial sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 16.....................................................................................................620
Table 10.3-49. Estimated number of fluvial sand and gravel deposits in Basin 17, both discovered and undiscovered, calculated using the MDD model. .................................................................625
Table 10.3-50. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model. .........................................................626
Table 10.3-51. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 17.....................................................................................................628
Table 10.3-52. Estimated number of fluvial sand and gravel deposits in Basin 18, both discovered and undiscovered, calculated using the MDD model. .................................................................633
Table 10.3-53. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones in Basin 18 calculated using the MDD model...........................................634
Table 10.3-54. Estimated number of sand and gravel deposits, both discovered and undiscovered, in alluvial fans in Basin 18.....................................................................................................636
Table 10.3-55. Estimated number of fluvial sand and gravel deposits in Area A, both discovered and undiscovered, calculated using the MDD model. .................................................................641
Table 10.3-56. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model. .................................................................642
Table 10.3-57. Estimated number of fluvial sand and gravel deposits in Area B, both discovered and undiscovered, calculated using the MDD model. .................................................................647
Table 10.3-58. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model. .................................................................648
Table 10.3-59. Estimated number of alluvial sand and gravel deposits, both discovered and undiscovered, in alluvial fans in Area B.....................................................................................................650
Table 10.3-60. Estimated number of fluvial sand and gravel deposits in Area C, both discovered and undiscovered, calculated using the MDD model. .................................................................654
Table 10.3-61. Estimated number of fluvial sand and gravel deposits in Area E, both discovered and undiscovered, calculated using the MDD model. .................................................................663
Table 10.3-62. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model. .................................................................664
Table 10.3-63. Estimated number of fluvial sand and gravel deposits both discovered and undiscovered in alluvial fans in Area E.....................................................................................................666
Table 10.3-64. Estimated number of fluvial sand and gravel deposits in Area F, both discovered and undiscovered, calculated using the MDD model. .................................................................671
Table 10.3-65. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model. .................................................................672
Table 10.3-66. Estimated number of fluvial sand and gravel deposits both discovered and undiscovered in alluvial fans in Area F. ........................................................................................................674

Appendix

Appendix 1    Geographic Information System (GIS) Project to Accompany the Non-Fuel Mineral Resource Assessment of Afghanistan