

# Mapping and Monitoring Artisanal Diamond Mining in Central and Western Africa Using an Integrated Geoscience Approach

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# USGS TECHNICAL ASSISTANCE

- The Kimberley Process (KP)
- The Clean Diamond Trade Act of 2003
- The U.S. Department of State's Special Advisor for Conflict Diamonds
- USAID PRADD Program



Fieldwork at ASM sites in Guinea, 2012

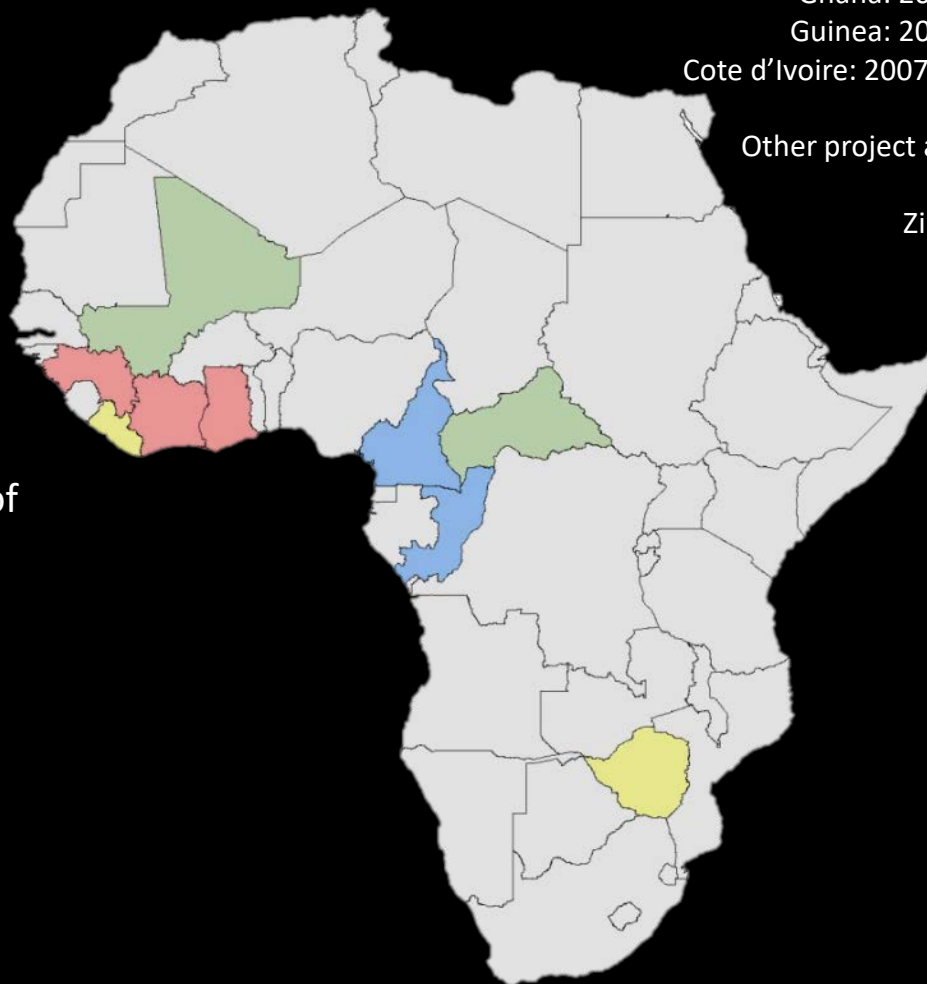


An official KP Certificate accompanying a diamond shipment from CAR

# RESOURCE AND PRODUCTION CAPACITY ASSESSMENTS

To conduct alluvial diamond resource assessments, an integrated approach has been developed comprised of three essential components:

1. Geologic and geomorphic data
  - Grade (carats/m<sup>3</sup>), gravel thickness, overburden material and thickness, bedrock material, geomorphic zone, etc.
2. Social and human geographic data
  - The number of miners, the roles of men, women, and children, tools used, number of days worked per year, seasonality of mining, reasons for mining, etc.
3. GIS and remote sensing technologies
  - Used to model the hydrography and geomorphology, identify and characterize pits, and monitor mining activities.



Resource Assessments

Mali: 2006-2009

CAR 2006-2009

Ghana: 2009-2010

Guinea: 2010-2012

Cote d'Ivoire: 2007-present

Other project activities

Liberia

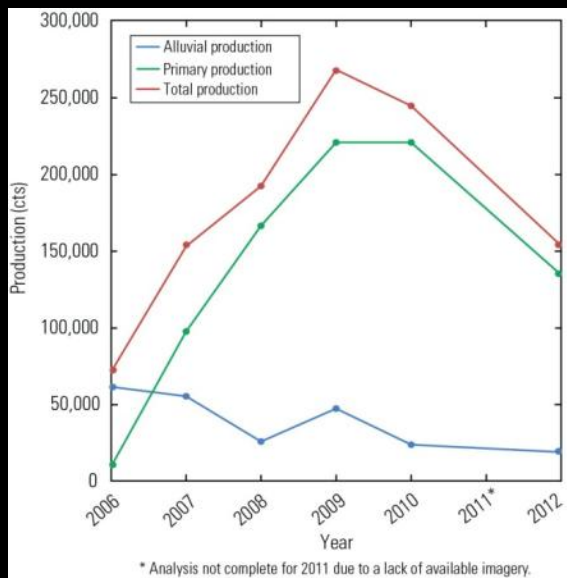
Zimbabwe

Map showing assessment locations



# PURPOSE

- It was necessary to develop a methodology for conducting regional and country scale assessments
  - A methodology was first developed by Barthélémy and others (2006) in an assessment of Congo-Brazzaville
  - This methodology has since been modified by Chirico and others (2010, 2012)
- This methodology provides a means of independently verifying a country's reported diamond production statistics
  - Assessment results are compared to the production statistics released to the KP
  - Areas falling far outside the estimated range are identified as areas of concern



Graph showing alluvial, primary, and total production for Seguela, Côte d'Ivoire from 2006-2012

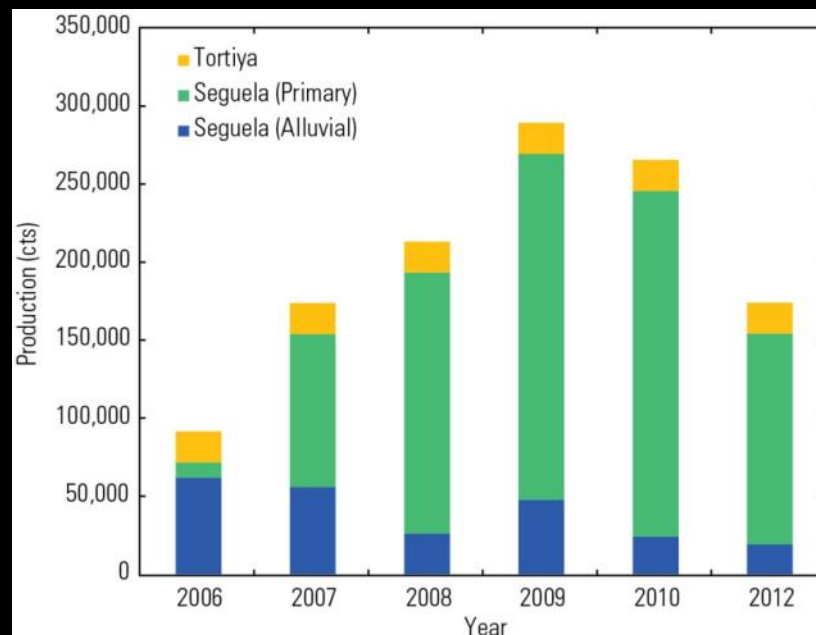
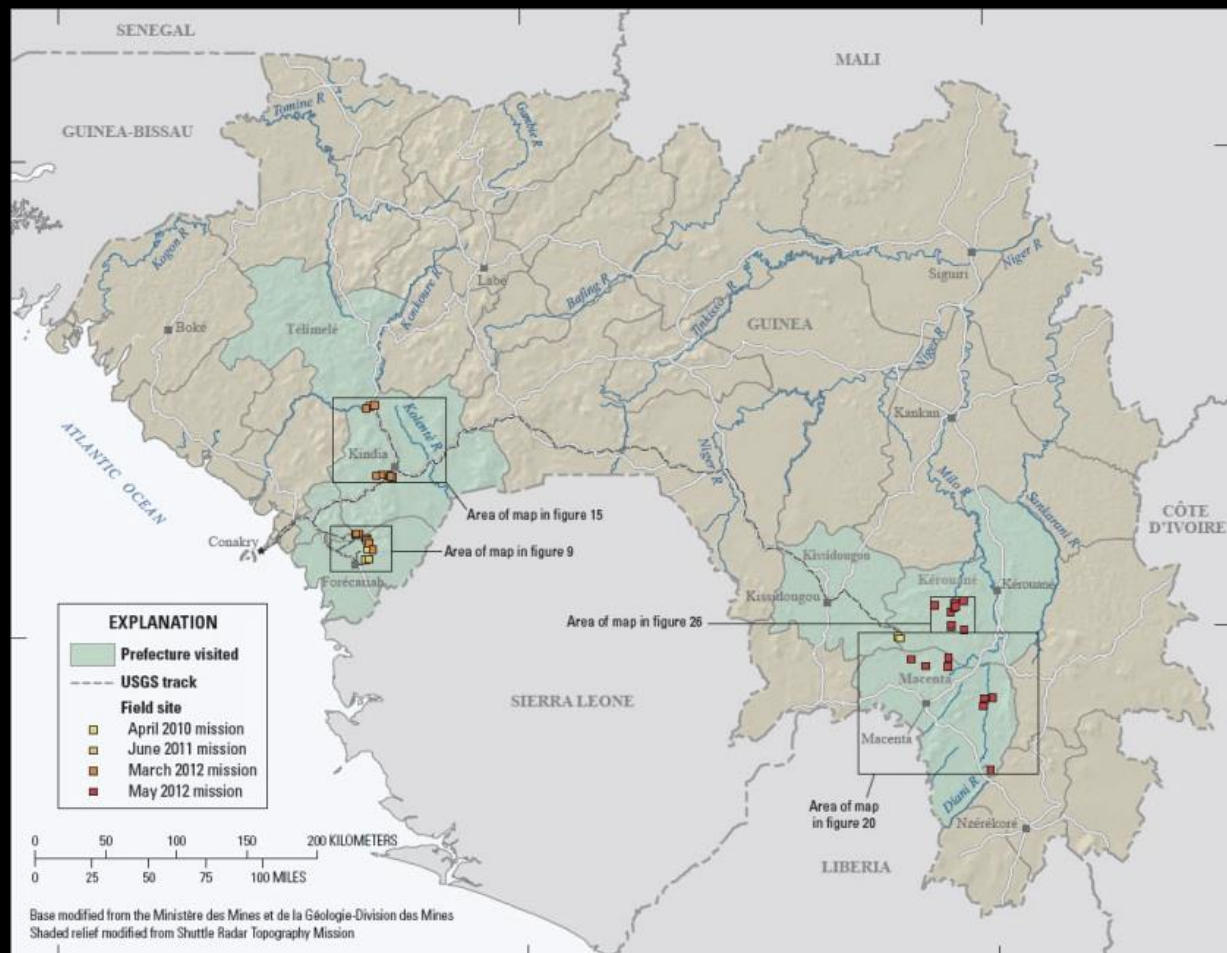
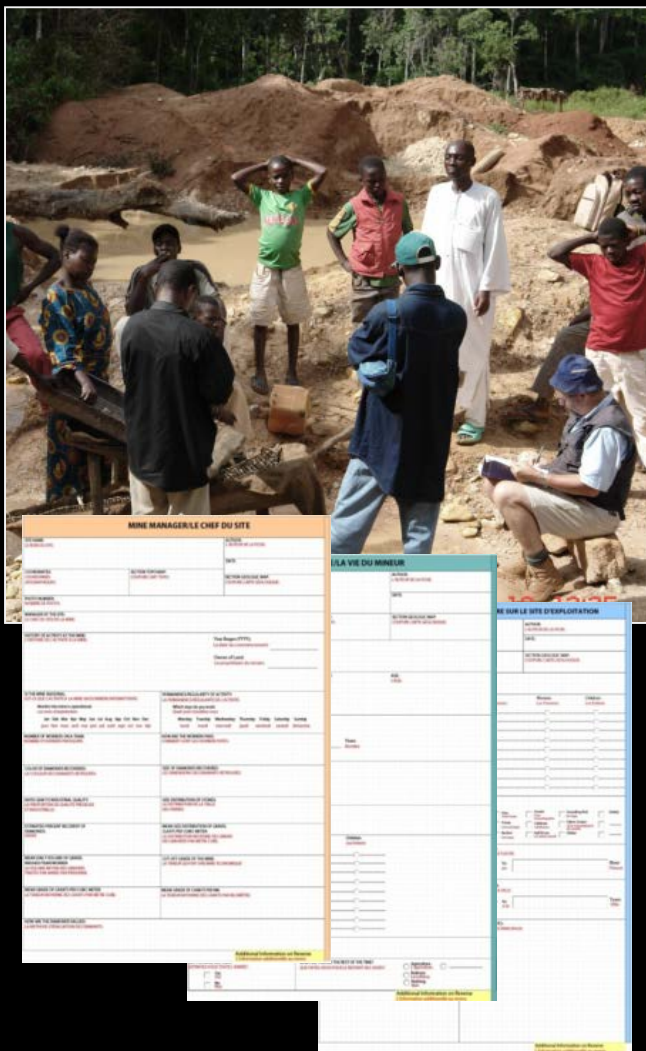


Chart showing production for Seguela and Tortiya, Côte d'Ivoire, from 2006-2012

# FIELD WORK

Collection of social and human geographic data through group interviews



Comprehensive questionnaire used for data collection

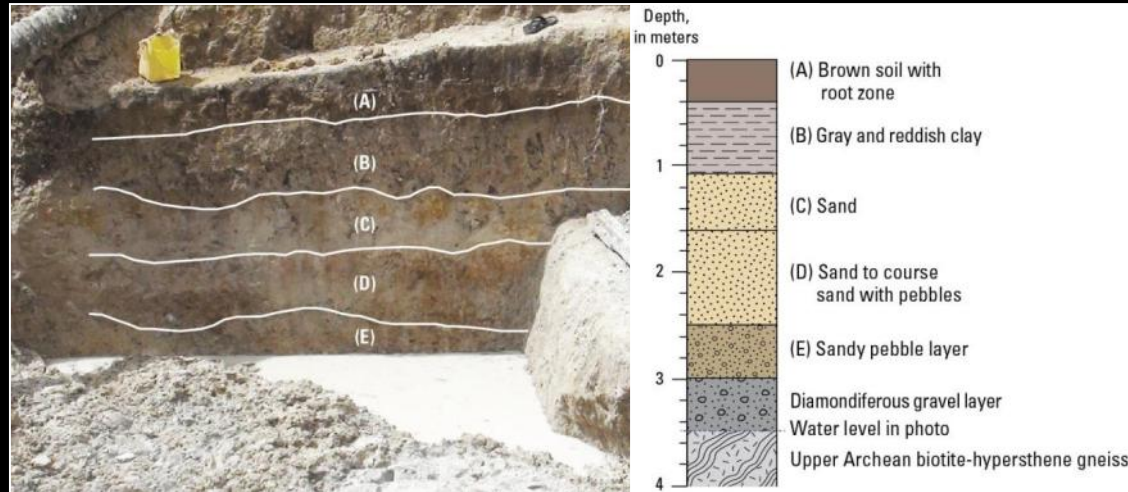


# FIELD WORK

Site characterization: Collection of geologic and geomorphic data through measurement, sampling, and observation



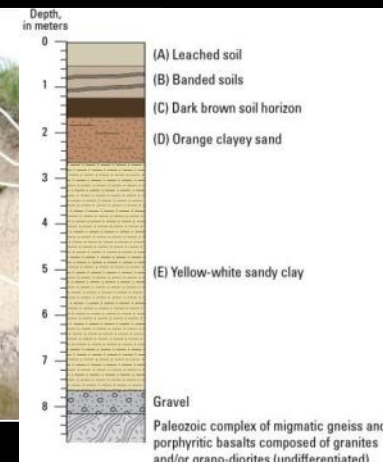
A researcher collecting data in Guinea



Artisanal mine pit with profile, Heremakono, Guinea

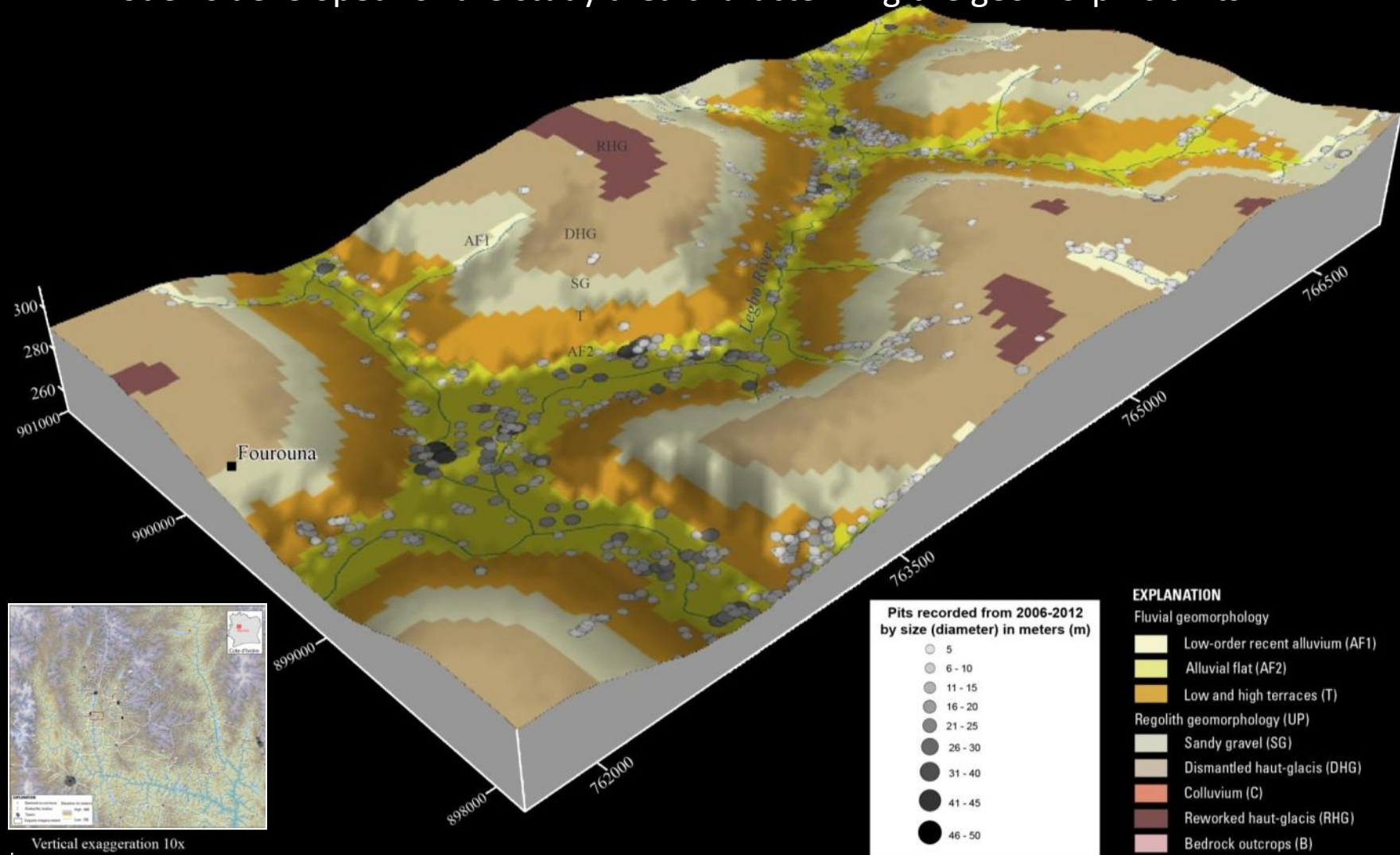


Artisanal mine pit with profile, Fondiya, Guinea



# GEOMORPHIC MODELING

- Deposit richness is closely related to local geomorphology
- A model is developed for the study area characterizing the geomorphic units





# PRELIMINARY SATELLITE IMAGERY ANALYSIS

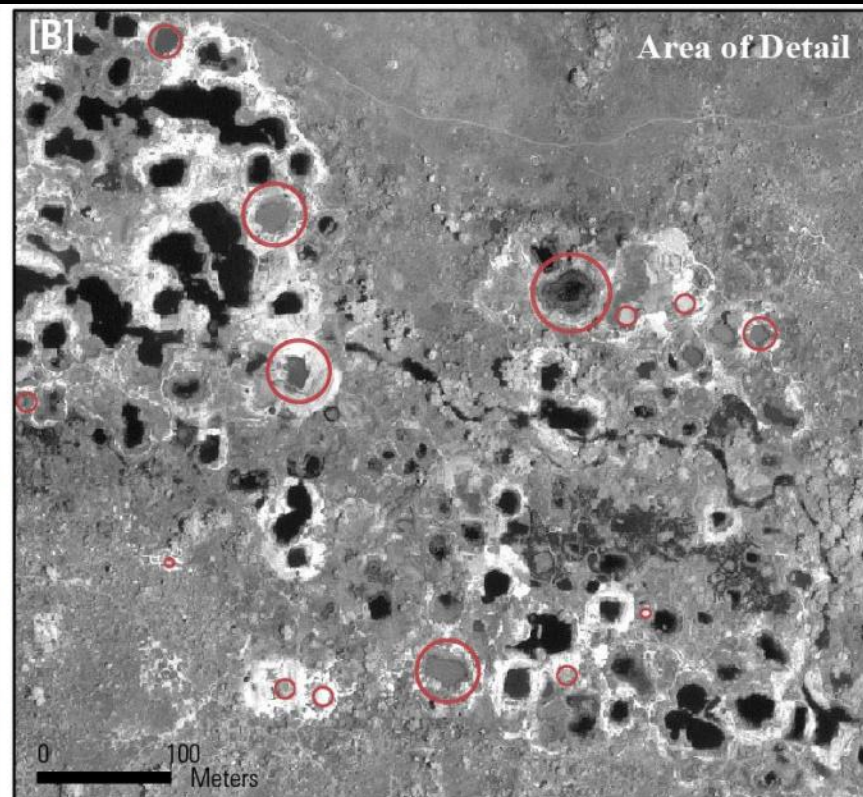
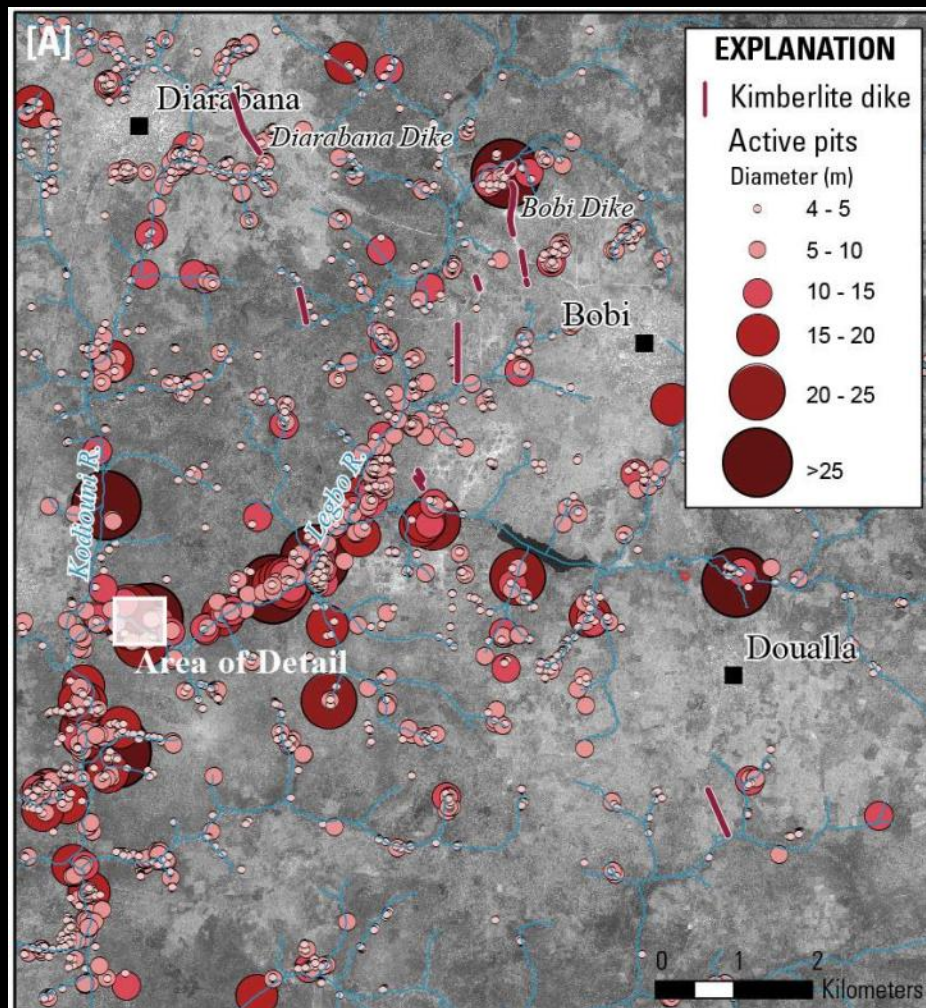
Satellite imagery can be used to identify active vs. inactive mine sites, thus providing information on the level of activity and identifying locations for field visits



Changes at a site over time, Bouramaya, Guinea



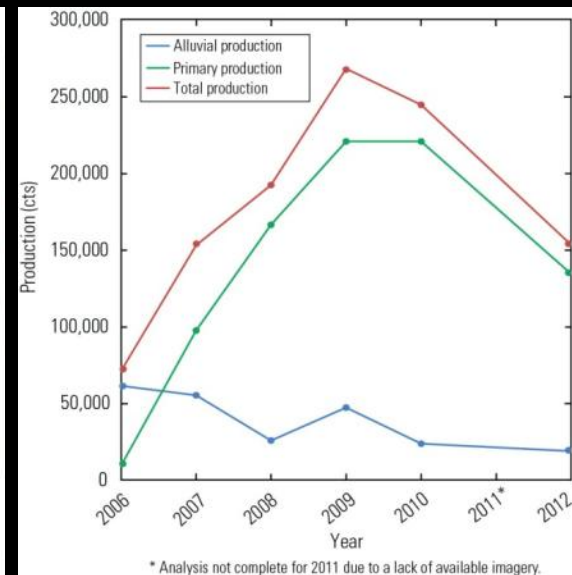
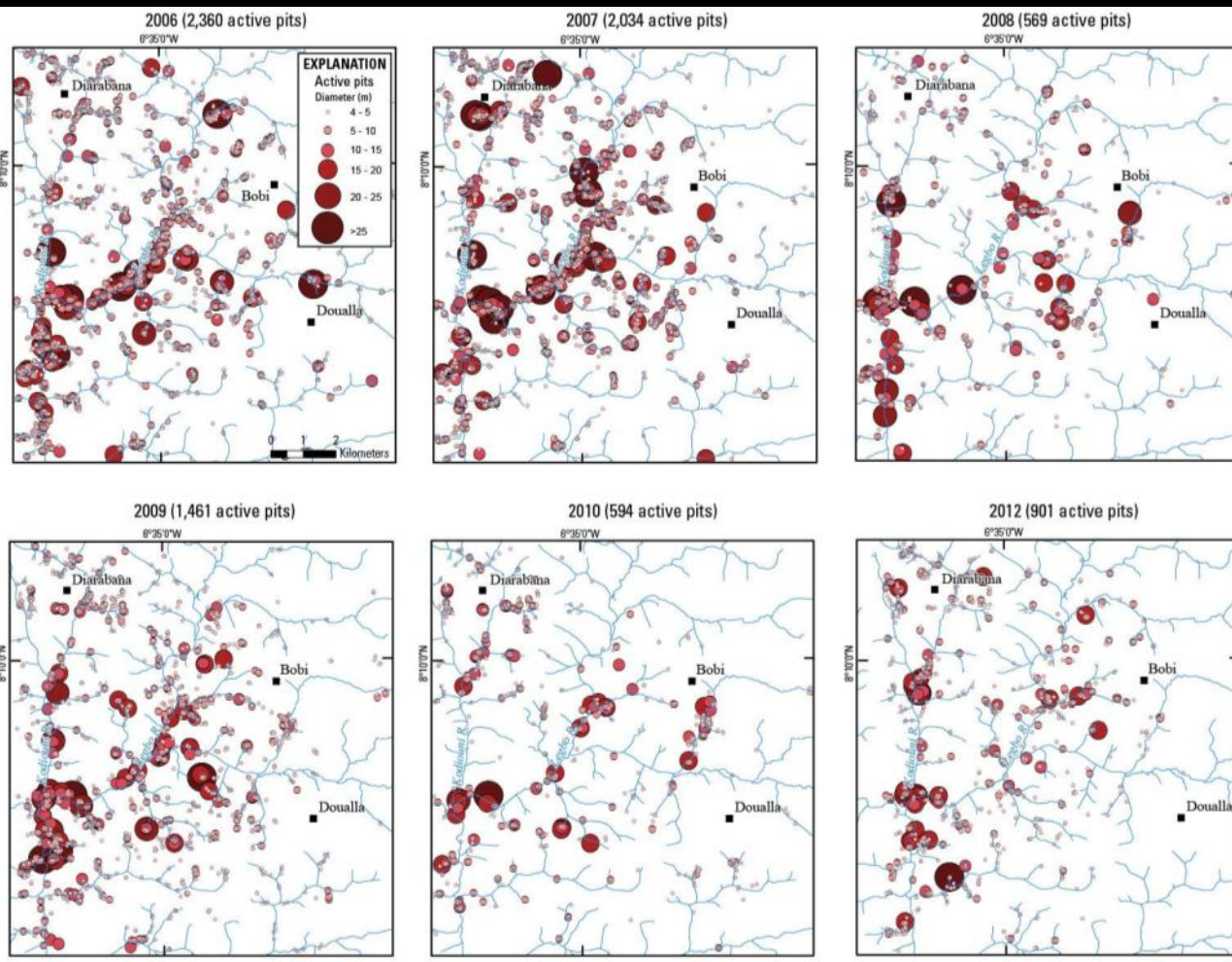
# SATELLITE IMAGERY ANALYSIS FOR LONG-TERM MONITORING



[A] Active mine sites interpreted from satellite imagery and represented by diameter [B] Area of detail showing active mine sites (circled areas) and currently inactive, previously mined pits (pits with dark reflectance).



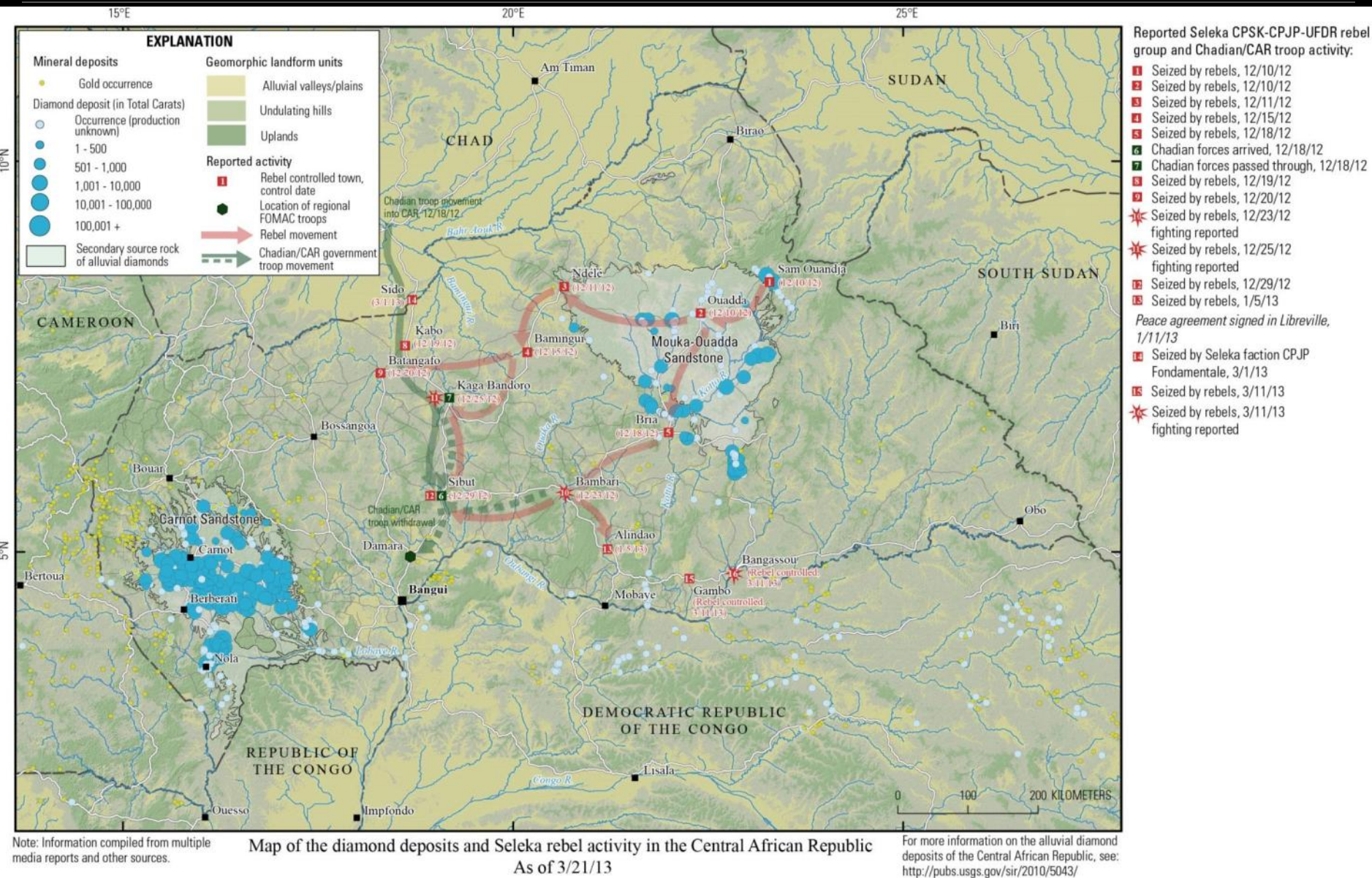
# TIME SERIES ANALYSIS OF ACTIVE PITS IN THE SEGUELA REGION, COTE D'IVOIRE



Graph showing alluvial, primary, and total production for Seguela, Côte d'Ivoire from 2006-2012

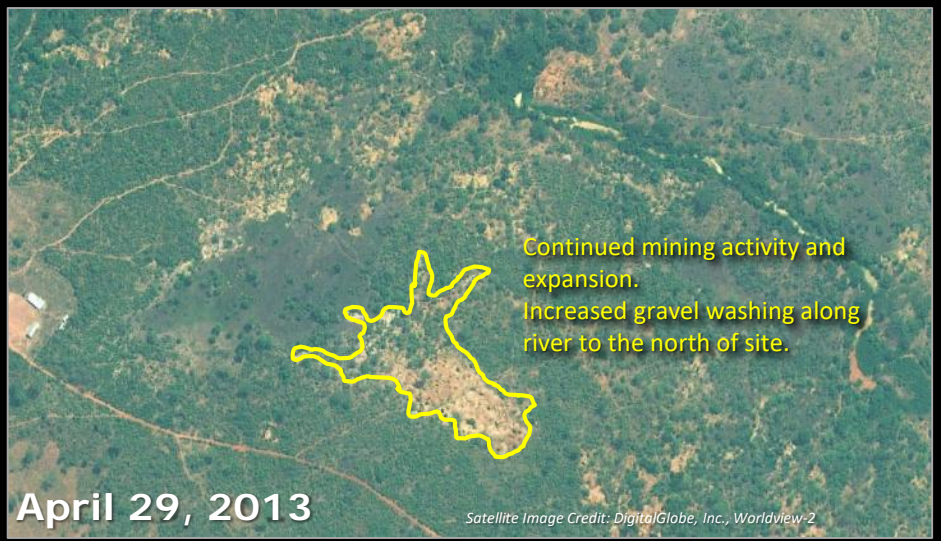
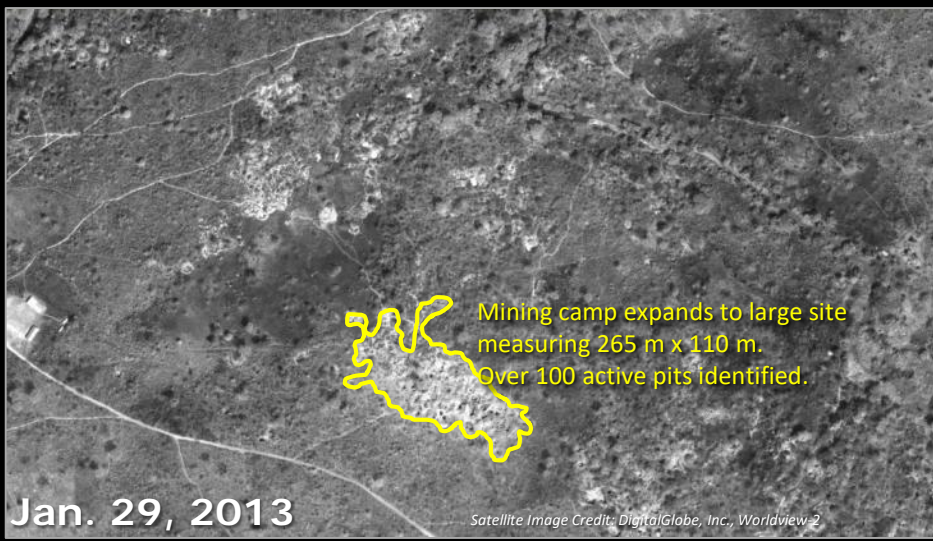


# CENTRAL AFRICAN REPUBLIC: SITUATION MAP (03-21-2013)





# CAR Monitoring: Sam Ouandja terrace mining and washing site



2006		2008		2012		2013					
2006	2008	2012				2013					
UFDR formed	Libreville Comprehensive Agreement signed between rebel groups (ARPD, UFDR, FDPC, CPJP) and Bozizé's government	Sept. Seleka CPSK-CPJP-UFDR coalition formed	Nov.	Dec.	Jan.	Feb.	March	April	May	June	
Birao, Ndele, Sam Ouandja, Ouadda attacked by UFDR				Sam Ouandja, Ouadda, Ndele, Bria seized by Seleka, in addition to 5 other towns	Peace agreement signed in Libreville between Seleka and Bozizé's government		Seleka breaks agreement and seizes 7 towns, reaching Bangui on March 23				



# TECHINICAL ASSITANCE WORKSHOPS AND TRAININGS

- As a component of the technical assistance plan, the USGS has conducted workshops and trainings in CAR, Mali, Ghana, and Guinea.
- Trainings typically include:
  - Hands-on practical field methods training
  - GPS training
  - Basic GIS skills training
  - Remote sensing imagery applications training
  - The transfer of laptop computers, GPS units, and/or GIS software to the Mining Ministry
  - A summary presentation of the results of the assessment

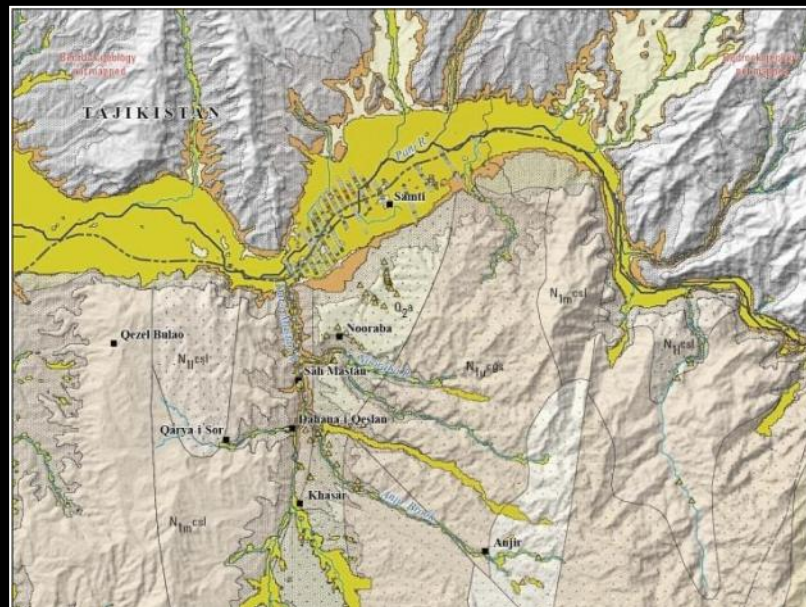


# SCIENCE APPLICATIONS

- The USGS Special Geologic Studies Project has conducted resource assessments of other minerals, including placer gold deposits in Afghanistan.
- Other potential applications include:
  - The assessment of tin, tantalum, and tungsten deposits in the Democratic Republic of the Congo
  - Burmese rubies and jade
- The data collected to complete these assessments have a wide range of applications, due to its diverse nature, including:
  - Human health (the use of mercury in gold mining)
  - Gender roles (the unique roles of men and women at mine sites)
  - Human migration (the movement of people from site to site)



A miner using mercury to sort gold



North Takhar placer gold deposits, Afghanistan



# USGS DIAMOND ASSESSMENT PROJECT SCIENTIFIC INVESTIGATION'S REPORTS (SIRs)

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## **Central African Republic:**

Chirico, P.G., Barthélémy, Francis, and Ngbokoto, F.A., 2010, Alluvial diamond resource potential and production capacity assessment of the Central African Republic: U.S. Geological Survey Scientific Investigations Report 2010-5043, 22 p. [<http://pubs.usgs.gov/sir/2010/5043>]

## **Mali:**

Chirico, P.G., Barthélémy, Francis, and Koné, Fatiaga, 2010, Alluvial diamond resource potential and production capacity assessment of Mali: U.S. Geological Survey Scientific Investigations Report 2010-5044, 23 p. [<http://pubs.usgs.gov/sir/2010/5044>]

## **Ghana:**

Chirico, P.G., Malpeli, K.C., Anum, Solomon, and Phillips, E.C., 2010, Alluvial diamond resource potential and production capacity assessment of Ghana: U.S. Geological Survey Scientific Investigations Report 2010-5045, 25 p. [<http://pubs.usgs.gov/sir/2010/5045>]

## **Guinea:**

Chirico, P.G., Malpeli, K.C., Van Bockstael, Mark, Diaby, Mamadou, Cissé, Kabinet, Diallo, T.A., and Sano, Mahmoud, 2012, Alluvial diamond resource potential and production capacity assessment of Guinea: U.S. Geological Survey Scientific Investigations Report 2012-5256 [<http://pubs.usgs.gov/sir/2010/5256>]

## **Côte d'Ivoire:**

Chirico, P.G., Malpeli, K.C., 2012, Reconnaissance investigation of the rough diamond resource potential and production capacity of Côte d'Ivoire: U.S. Geological Survey Scientific Investigations Report 2012-XXXX **USGS Peer Review Completed.**

# USGS PROJECT PUBLICATIONS ON ALLUVIAL DEPOSIT MODELING

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Chirico, P.G., Malpeli, K.C., 2012, A methodology for conducting national-scale alluvial diamond resource potential and production capacity assessments, with a focus on artisanal mining: U.S. Geological Survey Fact Sheet 2012-3128, 4 p. [<http://pubs.usgs.gov/fs/2012/3128>]

Chirico, P.G., and Malpeli, K.C., 2012, Summary of the diamond resource potential and production capacity assessment of Guinea: U.S. Geological Survey Fact Sheet 2012-3129, 2 p. [<http://pubs.usgs.gov/fs/2012/3129>]

Chirico, P.G., and Malpeli, K.C., 2012, Summary of the reconnaissance investigations of the diamond resource potential and production capacity of Cote d'Ivoire: U.S. Geological Survey Fact Sheet 2012-3130, 2 p. [<http://pubs.usgs.gov/fs/2012/3130>]

Chirico, P.G., and Malpeli, K.C., *in press*, A methodological toolkit for conducting field assessments of artisanal alluvial diamond deposits: U.S. Geological Survey Techniques and Methods, **USGS Peer Review Completed**.

Chirico, P.G., Malpeli, K.C., and Moran, T., 2013, Reconnaissance investigation of the alluvial gold deposits of the North Takhar Area of Interest: U.S. Geological Survey Open-File Report 2013-XXXX, *in press*.

Malpeli, K.C., Chirico, P.G., and McLoughlin, I.H., 2013, Reconnaissance investigation of the alluvial gold deposits in the Zarkashan Area of Interest: U.S. Geological Survey Open-File Report 2013-XXXX, *in press*.



# PROJECT PEER-REVIEWED JOURNAL PUBLICATIONS

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Chirico, P.G., Malpeli, K.C., and Trimble, S.M., 2012, Accuracy evaluation of an ASTER-Derived Global Digital Elevation Model (GDEM) Version 1 and Version 2 for two sites in western Africa: *GIScience and Remote Sensing*, v. 49, no. 6, p. 775-801.

Malpeli, K.C., and Chirico, P.G., 2013, The influence of geomorphology on the role of women at artisanal and small-scale mine sites: *Natural Resources Forum*, *in press*.

Chirico, P.G., and Malpeli, K.C., 2013, Using satellite imagery to prevent the trade of conflict diamonds and support artisanal mining communities: *Imaging Notes*, *in press*.

Chirico, P.G., and Malpeli, K.C., 2013, Conflict diamonds as an example of natural resource conflict: *Geospatial Intelligence Foundation Monograph Series*, *in press*.